GW SOLUTIONS
ASSESSMENT & PROTECTION OF GROUNDWATER

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Cortes Island Aquifer Health Assessment

Prepared for:

Cortes Housing Society

Prepared by:

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Executive Summary

The Cortes Island Aquifer Health Assessment, prepared by GW Solutions Inc. for the Cortes Housing Society, provides a comprehensive evaluation of groundwater resources on Cortes Island, located in the Salish Sea. This study aims to assess the health and sustainability of local aquifers to help guide future plans related to water supply, usage and sanitation for housing and development.

Cortes Island is home to the Klahoose First Nation and is within the traditional territories of the Homalco and Tla'amin Nations. Current development, focused in and around the small rural communities of Whaletown, Manson's Landing and Squirrel Cove, relies primarily on private wells for water supply, in addition to surface water from lakes, streams and springs. This assessment involved a comprehensive review of water sources, including provincial mapping, historical studies, field observations and local information. The island has abundant water resources, with 101 active water licenses and 223 registered wells, though there may be as many as 300 or more unregistered wells.

A three-dimensional geologic and water model was developed to evaluate local aquifers, revealing two new aquifers in the Squirrel Cove area. Fourteen water management areas were mapped based on watershed and topographic boundaries that influence groundwater movement. A gridded water balance model was developed to assess current water availability, considering climate factors, and the characteristics of soil and geology that influence groundwater recharge. The potential impact of climate change on the future water balance was also evaluated.

Current water use was estimated based on land use and occupancy patterns, and documented water sources. Groundwater stress, considering the ratio between annual water demand and recharge, was found to be low in sand and gravel and bedrock aquifers in the Manson's Landing and Squirrel Cove areas, while moderate to high stress was observed in fractured bedrock aquifers in Whaletown and Gorge Harbour, in part due to differences in the scale of the aquifer mapping. In water management areas, which identify a larger area for groundwater recharge, groundwater stress was considered low in all parts of the island. In all areas, water availability varies seasonally, with a summer period of minimal recharge and high water demand which must be supplied from aquifer storage replenished by winter precipitation. Drought conditions and a longer dry season are predicted in the future, emphasizing the importance of water conservation and development of storage. Bedrock aquifers are more vulnerable to contaminants introduced at the land surface, and to seawater intrusion in coastal areas where there is a high well density, and the wells are deeper. The Manson's Landing sand and gravel aquifer, AQ841, was interpreted to be hydraulically connected to the Hague Lake watershed, underscoring the potential benefit of integrated water resource management over a larger area.

The report emphasizes the need to establish local monitoring networks to track the changes in groundwater and surface water conditions on the island. Community education on water conservation and well maintenance, and use of best practices to reduce seawater intrusion hazards in vulnerable coastal areas will also benefit aquifer protection and sustainability. Overall, the assessment provides a foundation for informed decision-making to ensure the

long-term sustainability of Cortes Island's water resources, balancing development needs with environmental protection.

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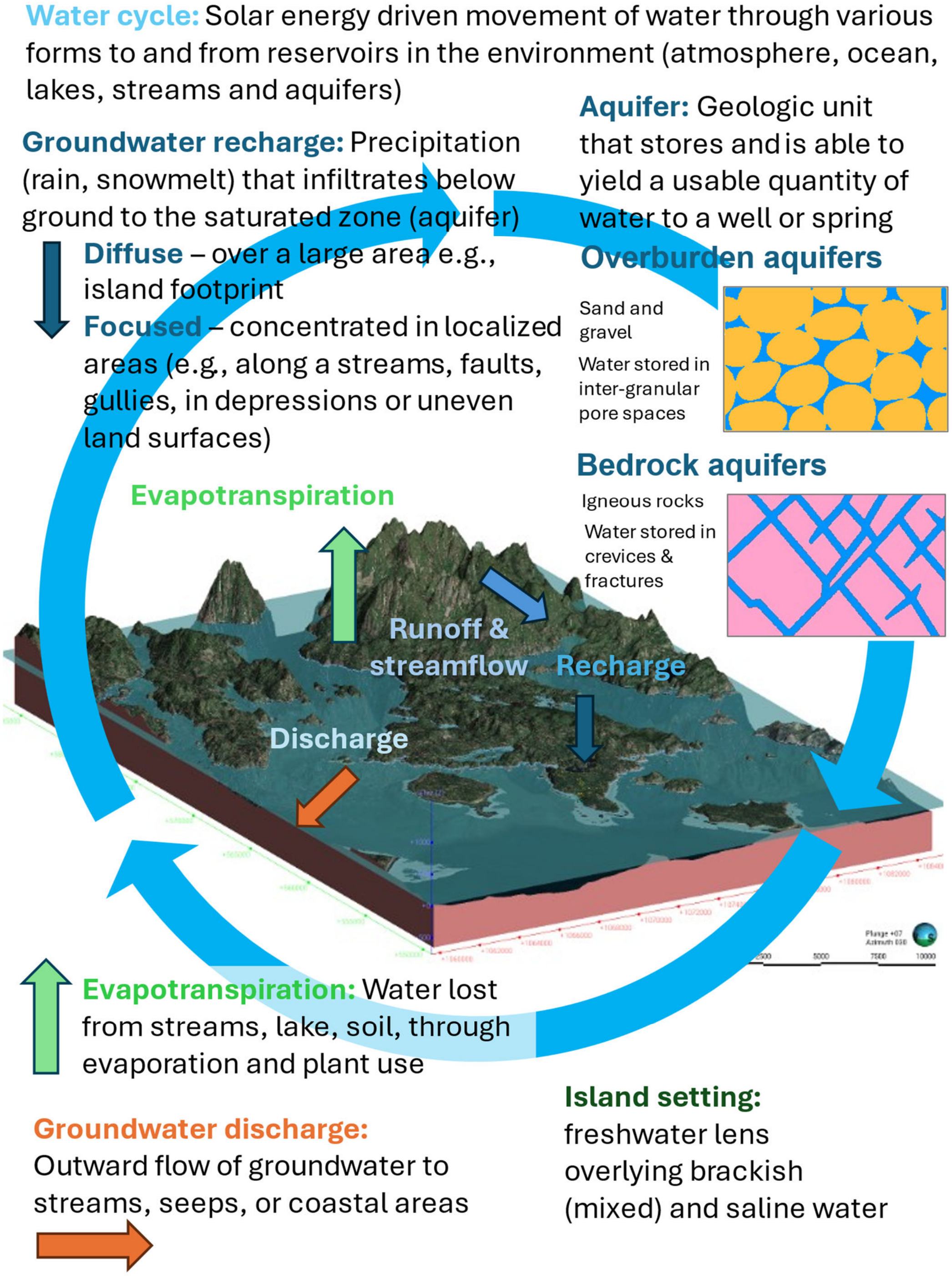

Water cycle: Solar energy driven movement of water through various forms to and from reservoirs in the environment (atmosphere, ocean, lakes, streams and aquifers)

Groundwater recharge: Precipitation (rain, snowmelt) that infiltrates below ground to the saturated zone (aquifer)

Diffuse – over a large area e.g., island footprint

Focused – concentrated in localized areas (e.g., along a streams, faults, gullies, in depressions or uneven land surfaces)

Aquifer: Geologic unit that stores and is able to yield a usable quantity of water to a well or spring

Overburden aquifers

Sand and gravel

Water stored in inter-granular pore spaces

Bedrock aquifers

Igneous rocks

Water stored in crevices & fractures

Evapotranspiration: Water lost from streams, lake, soil, through evaporation and plant use

Groundwater discharge: Outward flow of groundwater to streams, seeps, or coastal areas

Island setting: freshwater lens overlying brackish (mixed) and saline water

Cortes Island aquifer health study key definitions and terms.

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1 BACKGROUND

Cortes Island, is a 127 km^2 island within the Discovery Island archipelago, located 16 km northeast of Campbell River, accessed by ferry from Campbell River, via Quadra Island. Cortes Island is home to the Klahoose First Nation, whose traditional territory spans from Cortes Island to Toba Inlet (Klahoose First Nation, 2025). The island is also within the traditional territory of the Homalco First Nation and Tla'amin Nation (Rural Islands Economic Partnership, 2025).

Water supply for Cortes Island residents is obtained primarily from private wells, in addition to surface water from the island's lakes, springs and streams. In 2024, the Cortes Housing Society (CHS) obtained funding from the Real Estate Foundation of BC to map and quantify groundwater resources on the island, develop an understanding of aquifer carrying capacity and estimate groundwater availability for future growth within Cortes Island communities. The current groundwater study was completed in parallel with a multi-year ecological mapping project, intended to inventory and map environmental features on the island. At the same time, Strathcona Regional District has been undertaking a review of the Cortes Island Official Community Plan. These interrelated programs and inventories seek to improve education and awareness within the community, develop strategies to protect critical freshwater environments and resources on the island, and ensure that current and future development and land use policies are compatible with long-term water security.

The objectives of GW Solutions' work were to:

- Develop a hydrogeologic model to characterize groundwater sources on Cortes Island (unconsolidated and bedrock aquifers).
- Assess aquifer water balance under current conditions (groundwater recharge and availability compared to demand).
- Identify hazards related to water security on the island (areas of high water demand, vulnerability to hazards related to land use, sea water intrusion or other concerns).
- Consider water availability under future scenarios considering the impact of changes in land use and climate conditions.
- Provide recommendations for monitoring and water resource assessment and management on the island.

The general aquifer model and characterization was completed for Cortes Island as a whole, while a detailed water balance and groundwater availability assessment focused on the developed communities of Whaletown and Manson's Landing.

2 SCOPE

The scope of this project included the following four phases:

- Phase 1: Data inventory, compilation and assessment (including field-based observations and information gathering from local contacts).
- Phase 2: Development of a gridded water balance model for Cortes Island.
- Phase 3: Data gap, uncertainty, and sensitivity analysis.

- Phase 4: Water availability assessment for core community areas.
- Reporting: Preparation of a report on aquifer characterization and sustainability.

Some key factors considered in this project were:

- Changes in water demand considering current and future water demand based on land use scenarios.
- Predicted impacts of climate change on water balance within the study area.
- Potential interconnectivity between groundwater and surface water flow systems and importance of groundwater to aquatic habitats and freshwater ecosystems.
- Seawater intrusion hazards and prevention.

Project outputs include a geospatial database, geospatial model and maps that can be used by the CHS, SRD and the community to help guide planning and future development in a sustainable manner.

3 DATA COMPILATION

During the initial phase of the project existing information on geology and hydrogeology of the island was reviewed and compiled. The primary data sets and sources compiled for the study are summarized in Table 1. Additional sources and references are listed in the report sections below.

Table 1. Data sources and application within the study.

Source	Category	Data processing and application within the study
Province of BC	Groundwater Wells and Aquifers Database (GWELLS)	Data from GWELLS (Province of BC, 2025a) provided information on the locations and depths of wells, aquifer materials, depths of water bearing zones, groundwater levels, and relative aquifer productivity (estimated yield). Lithological data were cleaned and standardized to develop the Leapfrog model.
Province of BC and geospatial analysis	Mapped aquifers and lithological strata	There are six mapped aquifers on Cortes Island (Province of BC, 2025a). The boundaries of lithological strata and aquifer sub-regions appropriate for management scale were further defined considering watershed boundaries, groundwater flow directions (QGIS) and subsurface modelling (Leapfrog).
Province of BC	Aquifer vulnerability to sea water intrusion	Mapping of aquifer to vulnerability to sea water intrusion maps was obtained from the BC data warehouse (Water Protection and Sustainability, 2022). Methods and parameters used for sea water intrusion hazard mapping (Klassen and Allen, 2016; Sivak and Wei, 2021) and additional criteria were considered to refine the categorization of hazards within specific areas.
Province of BC	Water licenses	The provincial Water Rights Database contained information on the locations and licensed volumes for surface water Points of Diversion (POD's), including licensed springs, and groundwater Points of Well Diversion (PWD's) (Water Management, 2025a, 2025b).

Source	Category	Data processing and application within the study
Province of BC and water systems	Groundwater monitoring data	There are no active Provincial Observation Wells on Cortes Island. Regional comparisons were made based on monitoring in nearby areas, including Quadra Island (OW383) and private wells included in the Quadra Island Climate Action Network (Quadra ICAN) community groundwater monitoring network published in the Real-Time Water Data Tool (Ministry of Environment and Parks, 2025a). The data were used to interpret seasonal and regional trends in groundwater level fluctuation within different aquifer types.
Province of BC	Surficial, Quaternary and bedrock geology	Detailed geological mapping of the island was obtained from (Trettin, 2012a, 2012b; Trettin and Roddick, 2001). This provided information on geologic material types, formation process and origin (e.g. pre-glacial, glacial and post-glacial events, coastal processes such as the rise and fall sea level over geologic time) used to verify aquifer boundaries and develop the 3D model. Terrain resource information mapping and soil mapping for the island was also reviewed to interpret surficial material types and thickness (Dunn and Thrift, 1983; Talisman Projects Inc., 1979a, 1979b).
Province of BC	Digital Elevation Model	Topographic elevation of the landscape was obtained as digital elevation model (DEM) layer from BC Lidar Data Portal (GeoBC Branch, 2025). The data were used to develop a three-dimensional conceptual model of the island, highlighting surface topography, depressions, landforms and large scale physiographic and linear features that influence groundwater recharge and movement. Topographic elevation data were used to calculate slope (inclination of the ground) and aspect (direction of the slope) affecting precipitation infiltration and surface runoff, and to map groundwater flow direction, and the locations of recharge and discharge zones. The land cover DEM was combined with bathymetry mapping to indicate the depth of lake features (Fisheries and Oceans Canada, 2025; Natural Resources Canada, 2025a; Scouler Entrance Boating App, 2025).
Province of BC and local authorities	Water quality	Available data on groundwater and surface water quality was compiled from the Provincial Environmental Management System (EMS) database. Additional data were digitized from historical reports and information provided by water system operators.
Various	Water systems and water demand	Parcels with of non-domestic water use were determined from Island Health inventory of water systems (Island Health, 2020), GWELLS and the Water Rights database (Province of BC, 2025a; Water Management, 2025b) in addition to local directories and land use mapping (BC Assessment, 2025). Where possible, local water use data were obtained through personal communications with water system operators. Land use categories were used to infer water demand volumes based on published standards and guidelines (Miles, 2009; Ministry of Agriculture and Food, 2025; Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2012; Ministry of Health, Health Protection Branch, 2014; Statistics Canada, 2023a). Seasonal use and peaking factors were determined using long-term metered water system data from Regional District of Nanaimo and other island communities (Cowan, S., 2021; Regional District of Nanaimo (RDN), Water & Utility Services, 2025)

Source	Category	Data processing and application within the study
Province and local authorities, Strathcona Regional District	Cadastral mapping (lot boundaries) and land use	Current cadastral lot boundaries and BC Assessment actual land use were obtained from the Strathcona Regional District and used to determine the locations and purpose of water use.
Natural Resources Canada	Land cover and vegetation cover	Vegetation and land cover play an important bearing on the amount of evapotranspiration and runoff and were used to estimate groundwater recharge potential. Land cover classification was obtained from Natural Resources Canada (Natural Resources Canada, 2022).
Environment and Climate Change Canada and Pacific Climate Impacts Consortium (PCIC)	Historic climate data (long-term records and climate normals) and geospatial grid climate data (climate normals and future projections)	Statistical analysis of historic records on temperature and precipitation were completed based on compiled data from appropriately located climate monitoring stations (Environment and Climate Change Canada, 2024). The water balance model utilized gridded climate data (e.g. temperature and precipitation) and modelled future scenarios from the Pacific Climate Impacts Consortium (PCIC) (Pacific Climate Impacts Consortium, 2024).
Various	Existing hydrogeologic and environmental assessments	A detailed literature search was completed to gather and review information from previously prepared hydrogeologic and environmental studies.
First Nations	Traditional knowledge and history	GW Solutions and CHS representatives met with staff from the Klahoose First Nation and Qathen Xwegus Management Corporation who shared information on community development initiatives, water sources and monitoring.
Well operators, property owners and field survey	Local water resource inventory	Data on water sources, well construction characteristics, and water use were obtained through personal communications, interviews, and field visits to select sites in May 2025.

Figure 1. Cortes Island location and overview.

4 CORTES ISLAND WATER SOURCES

Water supply for residential and non-residential use on Cortes Island comes from numerous sources, including surface water—lakes, streams, creeks and springs—and groundwater from aquifers.

4.1 Surface water (streams, lakes and springs)

On Cortes Island surface water sources have been used historically and for current water supplies. There are seventeen gazetted lakes, eight of which are 3 hectares or more in area, listed in Table 2. Hague Lake at 81 hectares is the largest surface water source on the island with 9 current water licences (Figure 2), providing water for residential and farm properties nearest the lake, as well as for fire suppression and emergency response by the Cortes Fire Department.

Table 2. Cortes Island Lakes greater than 3 hectares (ha) in area

Name	Area (hectares)	Number of current water licenses
Hague Lake	81.0	9
Gunflint Lake	45.5	0
Robertson Lake	36.2	2
Cork Lake	27.5	0
Blue Jay Lake	14.4	0
Wiley Lake	12.2	0
Anvil Lake	10.8	2
Delight Lake	3.1	0

References: (GeoBC Branch, 2024; Strathcona Regional District, 2015; Water Management, 2025b).

In addition to the lakes, water is obtained from streams, creeks and springs, listed in Table 3. In most cases it is not required to measure or report water use volumes, therefore the licensed quantities are an approximate estimate of actual water demand. Currently, most water licenses are for domestic use (69% by volume*), followed by waterworks (8%*), commercial enterprises such as resorts (6%*), while only a small quantity of the licenses are associated with agricultural irrigation (5%*).*Per volume statistics exclude one large storage license for power generation.

Relatively unique to Cortes Island are the large quantity of licensed springs, representing 29% of licensed surface water sources. A spring that is in use as a water source may have the appearance of a shallow dug well (e.g. a shallow excavation typically less than 6 m deep, enclosed by cement rings, metal or wooden cribbing), or can include shallow stilling wells installed near the edge of a creek, or dugouts in perennial wetlands, examples shown in Figure 4. The locations of springs can indicate areas of groundwater discharge, including discharge associated with perched aquifers (i.e. water-bearing geologic layers overlying the principal aquifers. Spring sources are often shallow and may dry up or decline in productivity during the dry summer season, and, due to the characteristics of their installation and construction, springs may be vulnerable to contamination and therefore should be carefully managed (e.g., use source protection measures, and disinfect water prior to use) to reduce potential hazards to water users.

Table 3. Cortes Island licensed water sources.

Source name	Number of active (current) water licenses	Water use daily (m^3/d)	Water use annual ($m^3/year$)(Note1)	Note
Groundwater				
Aquifer 841 (Sand and gravel)	1	20.0	7,300	
Sayward Bedrock	1	1.0	365	Note 2
Surface Water				
Addison Creek	1	2.3	830	
Allen Creek	6	13.6	4,978	
Anvil Creek	2	5.7	1,446	
Anvil Lake	2	6.8	2,489	
Autumn Brook	4	0.5	3,866	
Barlow Brook	1	2.3	830	
Barrett Creek	2	4,900	1,788,373	Note 3
Basil Brook	4	10.2	3,733	
Batten Spring	1	4.5	1,659	
Beaumont Brook	3	2.3	8,231	
Brownline Spring	1	2.3	830	
Bullseye Spring	1	2.3	830	
Byrnes Brook	1	9.1	3,319	
Cahilty Brook	1	4.5	1,659	
Carr Spring	2	4.5	1,659	
Clegg Slough	1	2.3	830	
Coulter Creek	2	13.6	4,978	
Debbie Spring	1	2.3	830	
Des Marais Spring	2	4.5	1,659	
DeVinne Spring	1	2.3	830	
DeVoto Spring	1	4.5	1,659	
Dillon Creek	1	13.6	4,978	
Eratosthenes Brook	3	6.8	2,489	
Filberg Spring	1	2.3	830	
Frank Brook	1	2.3	830	
Gardner Spring	1	2.3	830	
Hague Lake	9	45.5	16,593	
Hansen Creek	2	6.8	2,489	
Henry Spring	1	20.5	7,467	

Source name	Number of active (current) water licenses	Water use daily (m^3/d)	Water use annual (m^3/year)$^{(Note1)}$	Note
Houghton Creek	2	4.5	1,659	
Hume Brook	2	4.3	1,560	
Jarvis Spring	1	2.3	830	
Kinkade Brook	3	4.5	1,858	
Lepp Spring	1	2.3	830	
McConnell Creek	1	4.5	1,659	
Mervyn Brook	2	4.5	1,659	
Michaels Brook	1	2.3	830	
Negrobills Creek	4	10.2	3,106	
Otter Spring	1	2.3	830	
Quartz Creek	1	2.3	830	
Robertson Spring	2	4.5	1,659	
Sager Brook	4	4.5	1,659	
Sager Spring	1	1.1	415	
Slack Creek	2	6.8	2,489	
Smith Creek	1	3.4	1,244	
Sprungman Spring	2	6.8	2,489	
Teitge Spring	1	2.3	830	
Thompson Spring	2	4.5	1,659	
Trueheart Spring	1	2.3	830	
Waling Spring	1	2.3	830	
Whiting Spring	1	2.3	830	
Zephyr Creek	1	2.3	830	
Zuk Spring	2	6.8	2,489	
Grand Total	101	5,215	1,913,590	

Notes:

[1] Actual water use often not measured and is typically not required to be reported or audited therefore may differ from the licensed quantity.

[2] Groundwater sources from unmapped aquifers are named according to water precinct and aquifer material.

[3] Barrett Creek includes a large license for power generation (.

4.2 Rainwater

Rainwater collected from rooftop collection systems and stored in cisterns or reservoirs is an important source of water supply in many BC coastal island communities where groundwater and surface water supplies are limited, e.g. Gabriola Island, Hornby Island and others. In comparison, rainwater collection does not appear to be in widespread use on Cortes Island, although it may be used as backup supply, be collected for irrigation, or used to provide water on properties without a well or nearby surface water source (Figure 3).

Figure 2. Surface water is an important source of water supply on Cortes Island. A) Hague Lake is the largest lake on the island and provides water for domestic drinking water supply for lakeside properties and for firefighting. B) Water supplies are also obtained from small streams such as Basil Creek (Brook) near Squirrel Cove.

Figure 3. Rainwater collection systems such as this one at the Cortes Island Recycling Centre can supplement or provide water supplies on properties without a well or nearby surface water source.

Figure 4. Spring water sources can have the appearance of A) shallow dug well, B) stilling well adjacent to a stream, or C) small dugouts. D) Natural wetland areas may indicate areas of spring discharge or be associated with perched water systems. Spring water sources are shallow and vulnerable to contamination and seasonal decline in water availability.

4.3 Wells

The primary source of water for most properties on Cortes Island is groundwater from wells drilled or constructed in unconsolidated (sand and gravel) or fractured bedrock aquifers. As of January 2025 the BC Groundwater Wells and Aquifers (GWELLS) database included records for 223 registered wells on Cortes Island, excluding sites listed as abandoned or decommissioned (Province of BC, 2025a). Roughly half of the registered wells, 113 wells, are constructed in unconsolidated materials such as sand and gravel, with an average depth of 55.2 m (181 ft), and an average estimated yield of 53 L/minute (14 US gallons per minute). The other 110 wells are drilled in fractured granitic bedrock. The number of registered wells constructed per year from pre-1970 to present is shown in Figure 5, reflecting different phases of land development. The peak of well registrations was in 2005, when BC's Groundwater Protection Regulation instituted new standards for well construction, maintenance, operation and closure (Province of BC, 2016a).

The provincial database is likely missing an unknown quantity of existing well records. The analysis of land use and water sources described in Section 6.4 suggests that there could be more than 300 unregistered wells on Cortes Island. Since February 2016, when the *Water Sustainability Act* came into effect, submission of well construction records to the database by well drillers became mandatory however compliance has been inconsistent among drilling contractors (Province of BC, 2014). Prior to 2016, well record submission was voluntary. It is therefore recognized that the inventory of wells in GWELLS is incomplete and that the database contains various errors and omissions. For example, the spatial location of a well on the property is often inaccurate, and wells may be mislocated or shown on the incorrect property, especially for older wells constructed prior to the widespread use of Global Positioning System (GPS) technology. Despite this, information from the GWELLS database is essential for identifying the extent of groundwater development and use, and for mapping subsurface geology and aquifers, etc.

Table 4. Registered wells in GWELLS database for Cortes Island.

Aquifer material	**Count**	**Average well depth**		**Estimated well yield**			
				Note 1	**Minimum**	**Average**	**Maximum**
Unconsolidated	115	ft	181	USgpm	1	14	259
		m	55.2	L/min	3.8	53	980
Bedrock	108	ft	320	USgpm	0.2	11	100
		m	97.5	L/min	0.6	42	379
Total	223						

Note 1: Estimated well yield is the well productivity estimated by the driller at the time of well construction but has not been verified by a longer duration well pumping test. The yield units here are reported in litres per minute (L/min) and US gallons per minute (USgpm). Total number of wells excludes decommissioned or abandoned wells.

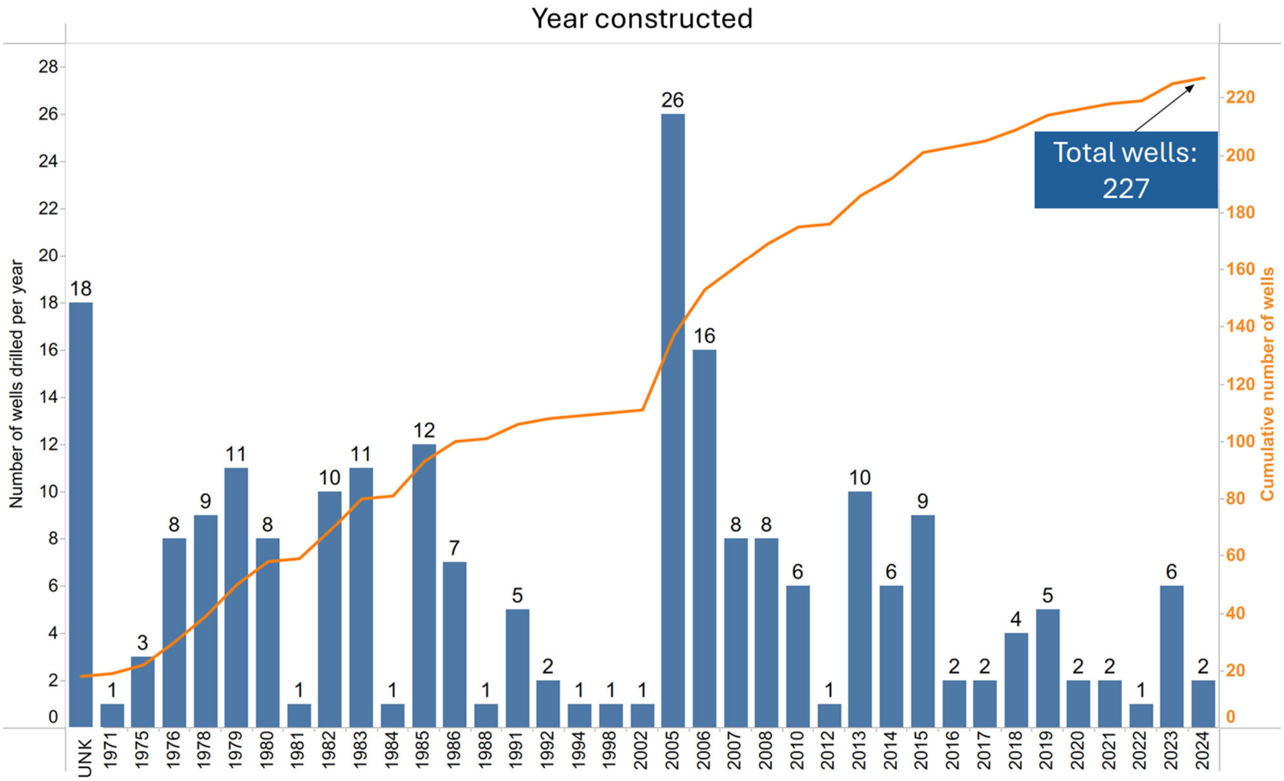


Figure 5. Cortes Island GWELLS registered wells by year of construction.

In 2016 new licensing provisions under the BC *Water Sustainability Act* (WSA) and Water Sustainability Regulation (WSR) came into effect (Province of BC, 2016b, 2014). While surface water licensing has been in place for over 100 years, the *Water Sustainability Act* now requires a water license for use of groundwater for non-domestic purposes (Ministry of Water, Land and Resource Stewardship, 2024). Domestic groundwater use, which does not require a license, is defined as residential water use on a single parcel, including for irrigation of a household garden up to 1000 m^2 in area, and water used for household pets and domestic livestock (e.g., poultry). Groundwater use for a non-domestic purpose, which requires a license, includes groundwater diverted for water supply systems (e.g., waterworks or multi-unit residential developments), industrial, commercial and agricultural use for irrigation and livestock. While an unknown number of license applications are in process or under review, it is also understood that in many small communities, such as on Cortes Island, there are numerous unlicensed water users including non-domestic groundwater diversion that must be accounted for in other ways.

4.4 Water systems

There are approximately twenty-two water systems on Cortes Island that provide water to public facilities such as schools, multi-unit housing sites (e.g. seniors village), community halls, stores, commercial campgrounds and hotels. These water systems were identified from data layers provided by Island Health (Island Health, 2020), published Drinking Water Reports and Summaries (Island Health, 2025), island directories and local contacts. All of the inventoried water systems utilize a groundwater source.

There are two neighbourhood-scale water systems, one located in the Whaletown area with 17 connections, and a second providing water to the Klahoose community on Tork Road which currently serves up to 120 residents. Water systems are regulated under the *Drinking Water Protection Act* and require a source approval and operational permit from Island Health (Province of BC, 2003, 2001). On First Nations reserves such as in the Klahoose community at Squirrel Cove, drinking water systems are managed by the nation and regulated by the First Nations Health Authority (First Nations Health Authority, 2025).

Figure 6. Example of drilled wells observed on Cortes Island. A) Domestic well in a pumphouse, and B) measuring groundwater level at the Rainbow Ridge development well.

5 HYDROGEOLOGY OF CORTES ISLAND

5.1 Aquifer conceptual and hydrostratigraphic model

This project involved development of a three-dimensional (3D) conceptual and hydrostratigraphic model of Cortes Island. Hydrostratigraphy refers to processes that affect the below ground component of the water cycle (hydro) based on the characteristics of different geologic materials or layers (strata). The model was used to evaluate and describe the factors influencing groundwater availability, movement, groundwater quality, and potential interconnection between aquifers, surface water bodies and coastal environments.

5.1.1 Hydrostratigraphic model methods

A 3D model of Cortes Island was developed using Leapfrog Geo software (Seequent, 2022) using the following input datasets.

Ground surface Digital Elevation Model (DEM):

A high resolution (1 m) DEM was not available for Cortes Island. Instead, a composite DEM layer was created by combining three layers from the following sources:

- National DEM with the resolution of 16 m by 16 m (Natural Resources Canada, 2025a).
- Ocean bathymetry data (Fisheries and Oceans Canada, 2025).
- Lake bathymetry data (Scouler Entrance Boating App, 2025). Bathymetry data were available for only Hague Lake and Gunflint Lake.

Well inventory from the provincial GWELLS database (Province of BC, 2025a) including the following information layers:

- Well lithology (description of subsurface geologic materials).
- Well depth.
- Depth and productivity of water-bearing fractures.
- Groundwater level measurements collected at the time of well construction.
- Well data were cleaned and standardized for input to the model.

The depth of the groundwater table surface was constructed using data from:

- GWELLS groundwater level measurements.
- Ground elevation in the location of selected surface water bodies at locations interpreted to be connected with the groundwater system, including Hague Lake, Gunflint Lake, Anvil Lake, Blue Jay Lake, Wiley Lake and Robertson Lake.

The geological component of the model was developed using the following sources:

- Geological map of the Cortes Island (Trettin and Roddick, 2001).
- Terrain maps (Dunn and Thrift, 1983; Talisman Projects Inc., 1979a, 1979b).
- GWELLS well log lithological data (Province of BC, 2025a).

The Cortes Island hydrostratigraphic model was used to interpret and describe the stratigraphy and hydrogeology of the island. Cross-sections were prepared which illustrate groundwater recharge and discharge zones, groundwater table depth, occurrence and thickness of confining layers, direction of groundwater flow, etc. The Leapfrog Model outputs also include a Leapfrog Viewer file that can be used by others to explore the subsurface geology and hydrogeology of the island.

An example output from the model showing the well locations and topography of the land surface in the Manson’s Landing area is shown in Figure 7.

The results of the model and interpretation of hydrogeology of Cortes Island are summarized in the sections below. Groundwater conditions on Cortes Island were initially characterized on an island-wide scale, considering groundwater levels and direction of groundwater flow, groundwater recharge and discharge locations, the potential for hydraulic connectivity between surface and groundwater systems, and description of the island aquifer setting within a saline coastal environment. A more detailed aquifer characterization and health assessment was then completed for the Manson's Landing, and Whaletown areas.

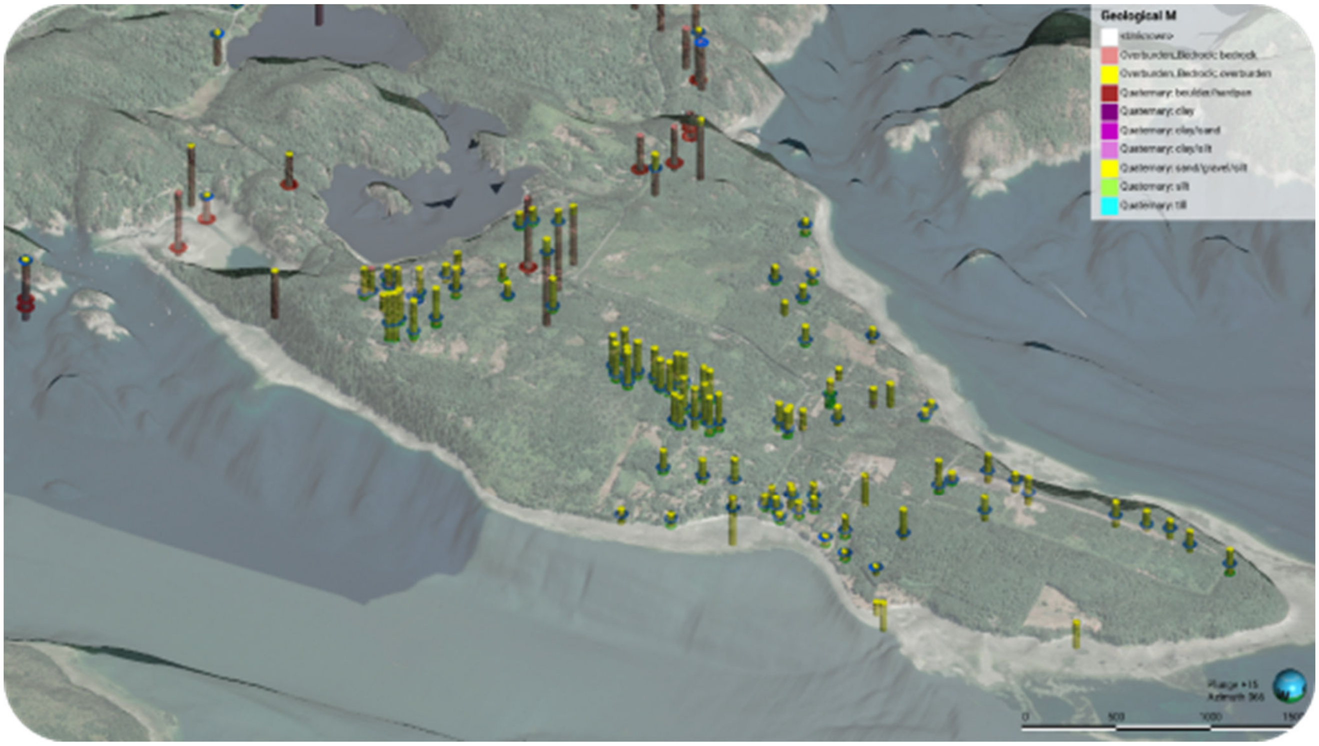


Figure 7. Surface topography, geologic mapping and well construction information were used to develop a 3D geospatial model of Cortes Island, example from Manson's Landing.

5.1.2 Model limitations

The hydrostratigraphic model is an interpretive tool to represent the characteristics of the island aquifers at a regional scale and is not meant to accurately represent conditions at the local or private lot level. Key limitations and sources of error associated with the input datasets should be considered when interpreting the 3D model and results, including:

- The resolution of topographic mapping was at a relatively course scale (16 x 16 m raster cells). High resolution (1 m scale) digital elevation mapping derived from Light Detection and Ranging (LiDAR) surveys was not available for the island, which could provide additional detail on physiographic features to help interpret boundaries of lithologic deposits, or features that influence groundwater recharge and movement.
- Well data (lithology, depth, productivity, and groundwater level) are sparse or unavailable for many areas including undeveloped areas in the central and north island.

- Well records vary in spatial accuracy. Some records may be mislocated on the wrong property, especially for older wells constructed prior to widespread use of field GPS units.
- Well drillers describe and interpret lithological materials in varied ways. For example, one person may record a material as "till" but it could also be described as compact, silty sand and gravel. Similarly, fine silt and clay appear similar in the field when discharged as drill cuttings. During the well lithology standardization, the material descriptions were kept as close as possible to the original description from the well record, to avoid bias in re-interpreting the material type.
- The subsurface stratigraphy including depths and thicknesses of low permeability sediments (clay, silt, till) is complex and challenging to represent in a simplified model. As such, the model zones with low permeability materials such as till, silt and clay should be considered qualitative, i.e. indicating presence/absence and relative thickness.
- Groundwater levels reported in the GWELLS database were measured during different seasons and over many years. Some field measurements and observations were collected during the field survey in May 2025 providing more recent reference points.
- There are no long-term groundwater monitoring locations on the island to provide information on seasonal or long-term trends.

5.2 Stratigraphy

The stratigraphy of Cortes Island is described in Table 5, based on (Trettin, 2012b).

Table 5. Cortes Island stratigraphy and hydrogeologic significance

Formation name	Origin and age	Description	Hydrogeologic importance
Salish sediments	Modern (post-glacial) deposits modified through processes (<10,000 years old)	Soil and sands, including beach and offshore deltaic deposits.	Soil layers are generally thin, with high permeability which allows rapid infiltration of precipitation.
Capilano-Vashon	Fluvial, glaciofluvial and glacial deposits formed during and following the Fraser Glaciation (18,000-12,000 years old)	On Cortes Island incudes Vashon Diamict (glaciomarine to marine silt, sand and clay, or "till"). Underlying the Vashon diamict, Spilsbury beds are interpreted as beach deposits accumulated during the period of higher sea level at the end of the Fraser Glaciation.	Vashon diamict forms low permeability confining layers that overlie bedrock and thicker Quadra Sand aquifers (e.g. AQ841). Saturated coarse grained sandy to gravel layers within or below the Vashon diamict interpreted as a source of water for shallow wells and springs.

Formation name	Origin and age	Description	Hydrogeologic importance
Manson's Landing Diamict	Deltaic, and nearshore slope deposits formed during the Frasure Glaciation	Stratified, poorly sorted compacted mix of gravel, sand, silt and clay. Variable thickness sand extent.	Low permeability, confining materials e.g. overlying AQ841.
Quadra Sand	Outwash deposits formed in front of advancing glaciers during the Fraser Glaciation (28,000 to 15,000 years ago)	Quadra Sand includes thick deposits of well sorted fine to coarse sand with minor gravel and silt, and thin discontinuous beds of silt and clayey sand. On Cortes, is interpreted as mainly occurring south of the "Uganda Line" which crosses Manson's Landing south of Hague Lake.	Quadra Sand forms the largest regional aquifer on Cortes Island in the Manson's Landing area(AQ841). Described in well logs as light brown or grey fine, medium to coarse grained sand, silty sand. Sand and gravel aquifer in Squirrel Cove may be associated with Quadra Sand, or younger deposits (e.g. Spilsbury).
Cowichan Head Formation	Formed during the Olympia non-glacial interval (23,000 – 41,000 years ago) before the Fraser Glaciation	Consists of river deposits (fluvial, estuarine), and marine sediments including clay, silt, sand and gravel. Found below Quadra Sand and overly bedrock or older diamict and sand deposits	Where present, occurs at or below sea level overlying bedrock. Few wells intercept this layer. Due to the depth and lower permeability, it is not an important groundwater source for the island.
Marina Island Diamict	Formed during the Semiahmoo Glaciation (>62,000 years before present)	Stratified and massive lodgement till (highly compacted, ice contact deposits), delta and diamict sediments (poorly sorted, sandy clay and silt with gravel)	Lower confining unit overlying Cortes Sand and bedrock. Few wells are likely constructed to or through this unit. Not easily differentiated from Cowichan Head formation based on well construction records.
Cortes Sand		Sand, silt, minor pebbles	Deep sand unit below Quadra Sand aquifer, identified in cliff exposures near Sutil Point. No wells are interpreted as constructed in this unit.

5.3 Aquifers

Within the GWELLS database there are six mapped and classified aquifers on Cortes Island, listed in Table 6 and shown in Figure 10 (Province of BC, 2025a).

Table 6. Cortes Island mapped aquifers

Aquifer Number	Year Mapped	Location	Aquifer material	Aquifer subtype	Aquifer subtype description	Litho-stratigraphic Unit	Area (km^2)
841	2007	South Cortes Island	Sand and gravel	4b	Confined sand and gravel – glacial	Glacial, pre-glacial and coastal (marine) deposits	9.5
NEW*	2025	Squirrel Cove Unconsolidated*	Sand and gravel	4b	Confined sand and gravel – glacial	Glacial outwash and coastal (marine) deposits overlying colluvial	3.1
842	2006	Cortes Bay	Bedrock	6b	Fractured crystalline bedrock	Intrusive igneous granodiorite	2.6
843	2007	Whaletown south	Bedrock	6b	Fractured crystalline bedrock	Intrusive igneous granodiorite	1.6
844	2007	Whaletown north	Bedrock	6b	Fractured crystalline bedrock	Intrusive igneous granodiorite	2.4
845	2006	Gorge Harbour	Bedrock	6b	Fractured crystalline bedrock	Intrusive igneous granodiorite	0.3
846	2007	Southeast of Hague and Gunflint Lake	Bedrock	6b	Fractured crystalline bedrock	Intrusive igneous granodiorite	2.9
NEW*	2025	Squirrel Cove Bedrock*	Bedrock	6b	Fractured crystalline bedrock	Intrusive igneous granodiorite	9.6

*New aquifers mapped by GW Solutions, not currently included in provincial GWELLS database.

5.3.1 Unconsolidated aquifers

Mansons Landing Unconsolidated Aquifer (AQ841)

The primary unconsolidated aquifer on Cortes Island is Aquifer 841 (AQ841), 9.5 km^2 in area, which extends from the south side of Hague Lake southwestward down to the end of the Sutil Peninsula (Province of BC, 2025b). This aquifer is an essential water supply for domestic, agricultural and water system wells from the Manson’s Landing village area to Sutil Point.

Squirrel Cove Unconsolidated Aquifer

The hydrostratigraphic model developed for this study identified and mapped the boundary of an unconsolidated aquifer in the Squirrel Cove area not currently included in the provincial aquifer inventory. The Squirrel Cove unconsolidated aquifer has an approximate area of 3.1 km^2 and is the water source utilized by domestic users and water systems in the Squirrel Cove area, including the Klahoose First Nation community. Mapping and initial classification of this aquifer is included in section 8.3.

Figure 8. A) Unstable coastal bluff southeast of Manson's Landing shows silt and fine sand layers which overly the principal aquifer AQ841. B) Land clearing near Squirrel Cove has exposed a locally thick deposit of gravel and sand which overlies and forms a previously unmapped unconsolidated aquifer in this area.

5.3.2 Fractured bedrock aquifers

There are five bedrock aquifers in the GWELLS database, including AQ843 and AQ844 in the Whaletown area, AQ845 on the north side of Gorge Harbour, AQ842 along Cortes Bay, and AQ846 in the Manson's Landing area, east of Hague Lake and Gunflint Lake.

Following the BC Aquifer Classification System methodology, bedrock aquifers on Cortes Island have been delineated based on the area of groundwater development, locations of reported wells, and topographic or watershed divides which influence the direction of runoff and groundwater flow (Berardinucci and Ronneseth, 2002; Hodge, William S., 2007a). However, the boundaries of existing and newly mapped bedrock aquifers may be revised over time as new wells are drilled.

All of the fractured bedrock aquifers on Cortes Island are comprised of granitic igneous intrusive rocks (Hodge, William S., 2007a). Geologic mapping for the island describes the bedrock as granitoid massifs and dykes, Middle Jurassic to Lake Cretaceous in age, including biotite granite, granodiorite and tonalite (Trettin, 2012a). Wells drilled in fractured granitic bedrock aquifers have moderate yields and groundwater is transmitted through large blocky fractures (Figure 9, A,B,C). Bedrock aquifers are moderately to highly vulnerable to contamination from the land surface, depending on the presence and thickness of overlying fine-grained sediments such as clay or silt. Surficial deposits overlying the bedrock are generally thin in upland areas, and thicker in lowlands and depressions (Figure 9, D).

In the Squirrel Cove area, five wells registered in the GWELLS database are constructed in granitic bedrock, however there is no provincially mapped bedrock aquifer in this area. A preliminary boundary for a bedrock aquifer at Squirrel Cove was delineated based on the boundary of the Basil Creek watershed, assumed to be both a topographic and groundwater flow divide.

Figure 9. Granitic bedrock outcrops on Cortes Island exhibit large blocky fractures that can store and transmit groundwater. A) In coastal areas such as Cortes Bay, wells that intercept fractures connected to coastal zones may draw in brackish (mixed) or saline water. B) Large vertical and horizontal fractures in outcrop near Manson's Landing. C) Water seepage from outcrop near the Whaletown ferry terminal. D) Easter Bluff looking south: In upland areas, the bedrock is overlain by a thin layer of soil or sediments promoting more rapid runoff and increasing vulnerability to contaminants introduced at the surface .

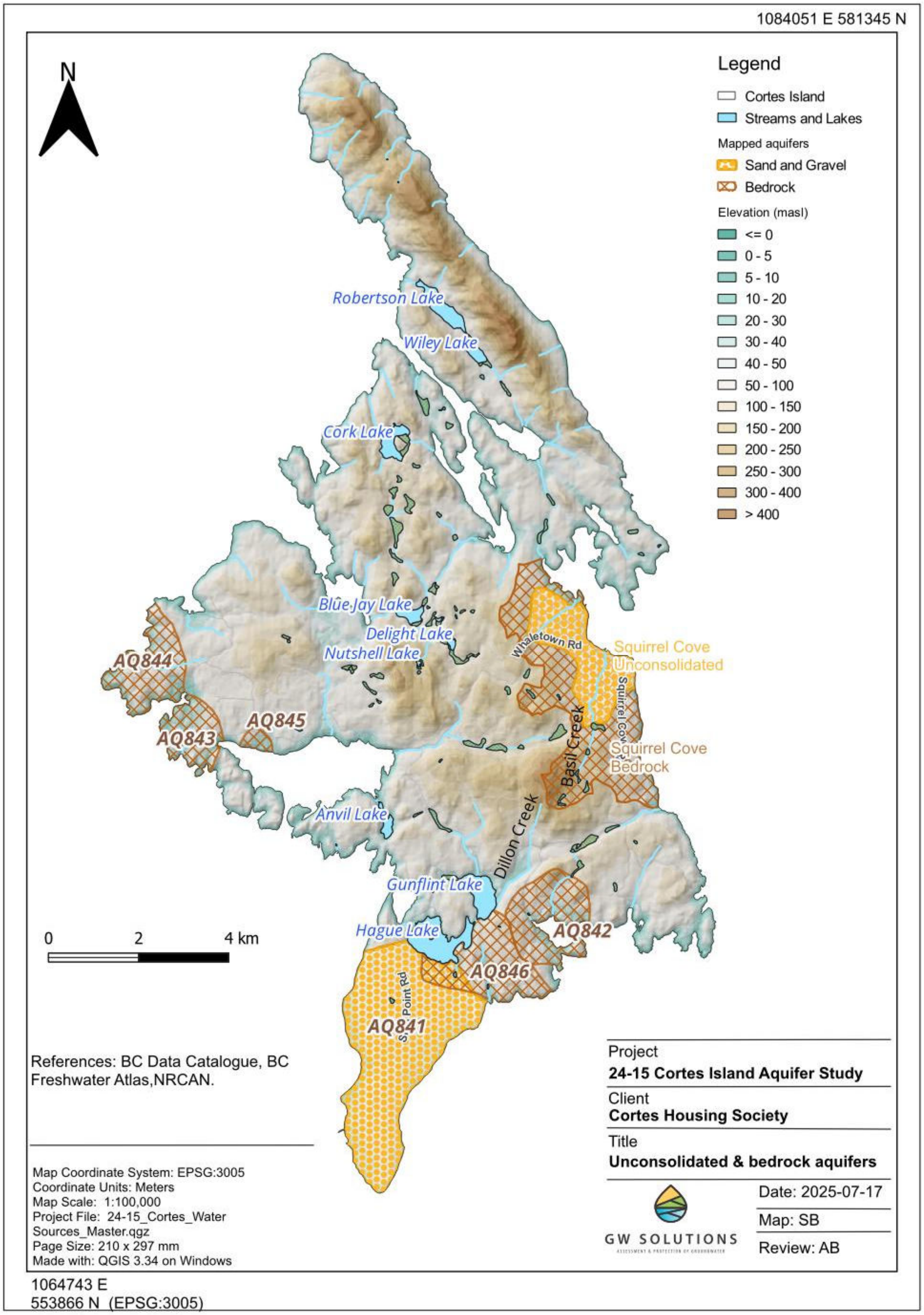


Figure 10. Overview of mapped unconsolidated and bedrock aquifers on Cortes Island.

5.4 Groundwater depth and direction of flow

Figure 11 illustrates a map of groundwater depth below ground on Cortes Island. The blue arrows show the inferred direction of groundwater flow. Generally, groundwater is expected to flow from high to low elevation under the influence of gravity, while groundwater levels exhibit a pattern similar to topography (Fetter, 2018). In upland areas and at higher elevation the groundwater table is often deeper below the ground surface. In comparison, the groundwater table tends to be shallower below ground at lower elevation.

On Cortes Island, groundwater levels below bedrock ridges can be 100 m or greater below the ground surface. Near the coast, and along stream and lake valleys, observations of shallower groundwater levels—5 m or less below ground—can indicate zones of groundwater discharge.

Shallower groundwater levels are observed, for example, around Hague Lake and Gunflint Lake and along the northeastern trending valley northeast of Gunflint near Seaford Road and indicate the potential for hydraulic connection between the surface water and groundwater in these areas.

5.5 Monitoring data sources

There are currently no provincial observation wells on Cortes Island, although some data are being collected by private well owners and operators. Regional trends in groundwater level variability for different aquifer subtypes can be inferred from monitoring on adjacent islands. For example, long-term monitoring data are available from the provincial OW383 on Quadra Island which measures groundwater level and temperature in unconsolidated aquifer AQ751 (Ministry of Environment and Parks, 2025b). Quadra Island Climate Action Network (Quadra ICAN) implemented a community monitoring network which monitors groundwater level, temperature, and electrical conductivity in 12 wells across the Quadra Island. Data from the provincial and community monitoring networks are published on BC Real Time Water Data Portal (Aquarius) (Ministry of Environment and Parks, 2025a). Installation of provincial observation wells, and development of a local Cortes Island monitoring network would help to improve understanding of local groundwater conditions and changes over time.

5.6 Water quality

Assessment of groundwater quality was outside the scope of the current assessment. However, water quality results from seven sites were collated from well operators and previous hydrogeologic studies on the island. A preliminary review of the data from the Provincial BC Environmental Monitoring System was completed. Groundwater quality data are available in the EMS database for thirteen wells sampled from 2001 to 2008. Further collation and evaluation of water quality is recommended to understand and characterize baseline groundwater conditions such as the range and average concentration of natural contaminants (e.g., iron, manganese, arsenic), and to evaluate future impacts from land use or sea water intrusion in vulnerable areas.

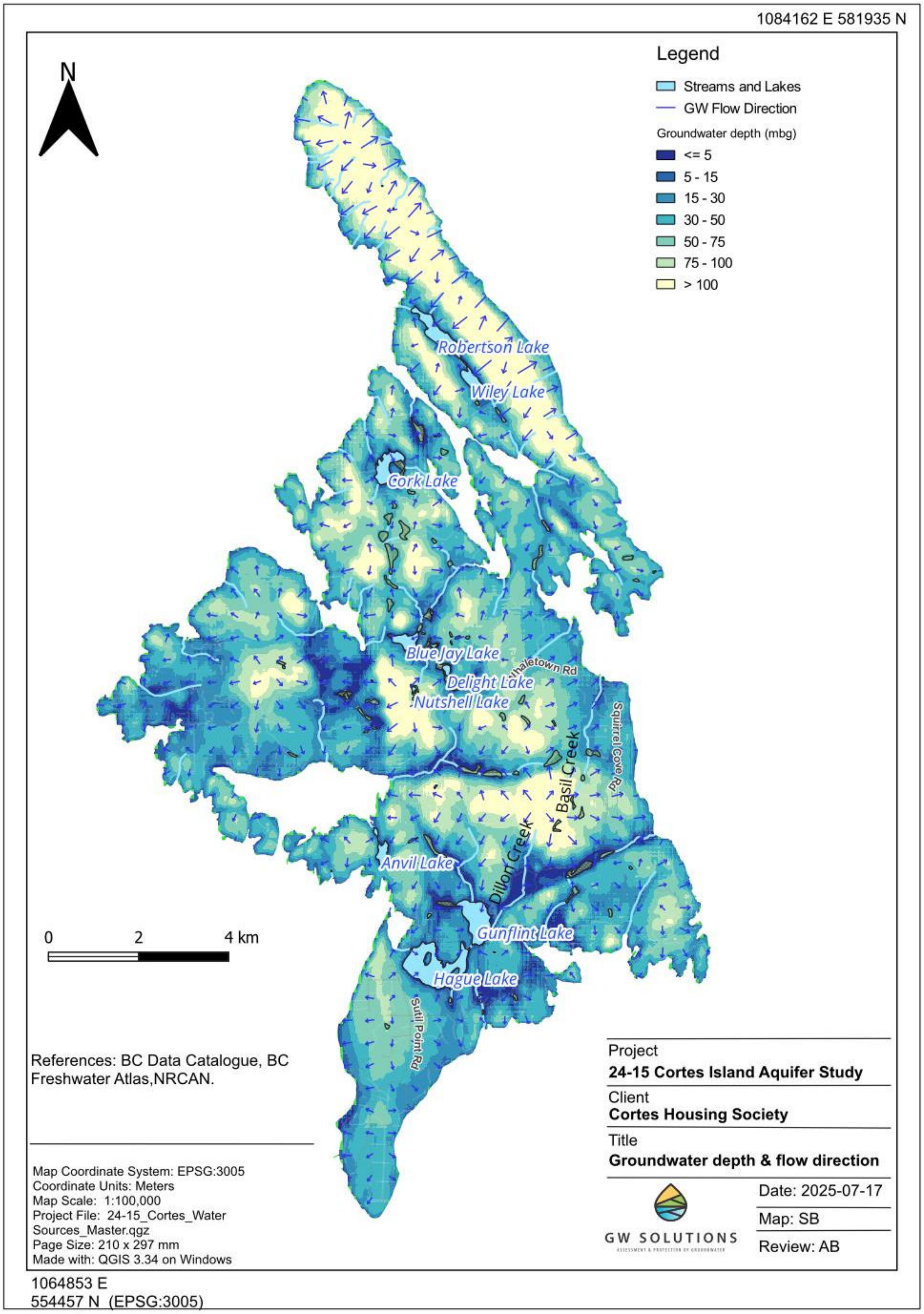


Figure 11. Cortes Island depth to groundwater and inferred direction of groundwater flow.

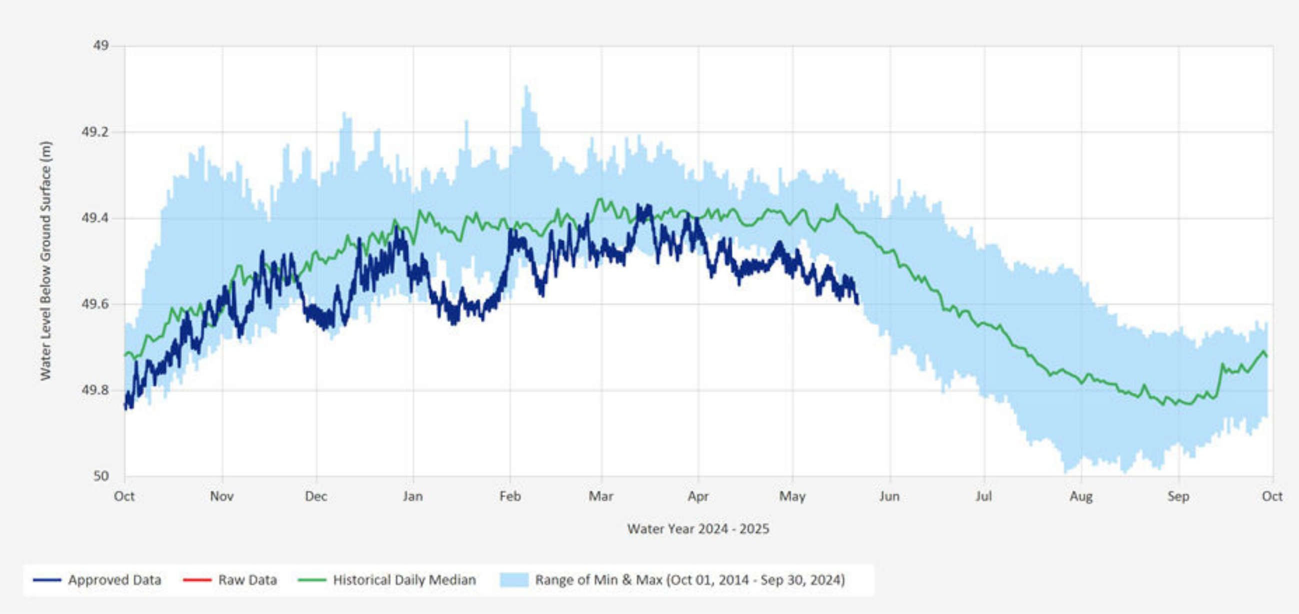


Figure 12. Groundwater level statistics chart for OW383, Quadra Island Unconsolidated Aquifer AQ751. Annual groundwater levels exhibit an annual range up to 1 m, while current year levels are slightly lower than the long-term (10-year) trend (Ministry of Environment and Parks, 2025b).

5.7 Water management areas

To define areas for more detailed analysis, including water availability assessment, Cortes Island was divided into fourteen water management areas, shown in Figure 13. The regions were differentiated based primarily on watershed or topographic divides which influence the direction of surface and groundwater flow, interpretation of the hydrostratigraphic model, aquifer boundaries, and potential hydraulic connectivity between surface and groundwater flow systems. These identified groundwater regions were used within subsequent analyses. A detailed characterization and water balance assessment was completed for the two most developed management areas of Whaletown and Manson’s Landing.

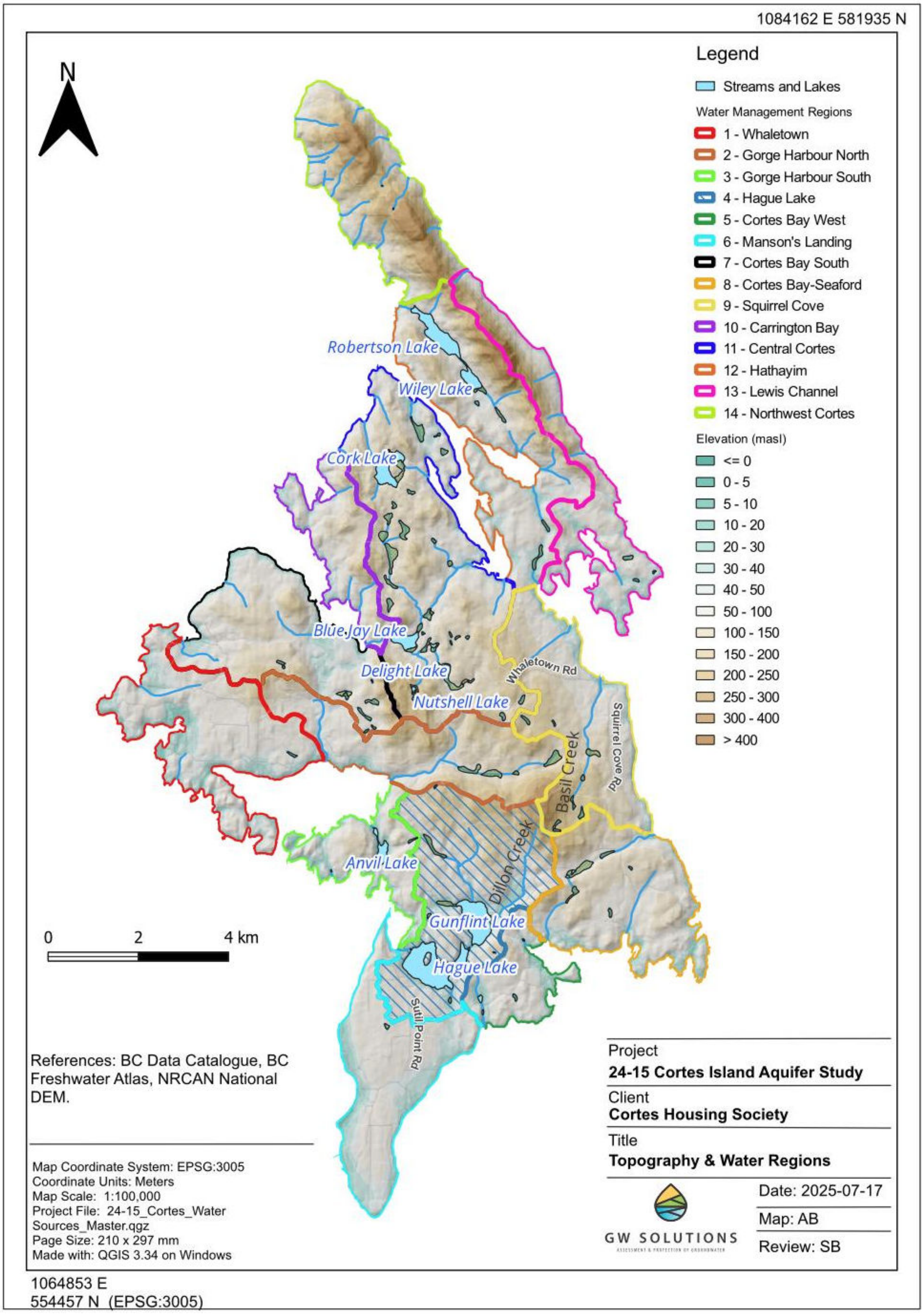


Figure 13. Cortes Island groundwater management areas.

5.8 Aquifer Hazards and Sustainability Indicators

A regional aquifer summary was prepared for the key management areas—Whaletown, Manson's Landing-Hague Lake, and Squirrel Cove—which describes the aquifer conceptual model, water balance assessment and other indicators of aquifer health. These regional assessments, provided in Section 8, include maps and geologic cross-sections prepared using the results of the 3D model which were then used to interpret and describe subsurface conditions and aquifer processes.

Indicators of aquifer health and sustainability also considered in the aquifer health assessment include vulnerability to contamination, likelihood of hydraulic connectivity between surface and groundwater systems, and seawater intrusion hazard, described further below.

5.8.1 **Aquifer Vulnerability to Contamination**

Aquifer vulnerability to contamination from the land surface was described qualitatively, considering the presence, mapped extent and relative thickness of low permeability confining materials such as clay, silt or till overlying the aquifers, groundwater depth and other factors. Previous provincial studies, for which map layers are available on iMapBC, have assessed aquifer intrinsic vulnerability to contamination assessed using the DRASTIC method, described in (Denny et al., 2007; Liggett and Gilchrist, 2010; Newton and Gilchrist, 2010; Province of BC, 2025c). Completion of detailed vulnerability assessment and assessment of contamination hazards inventory including land use and contaminant sources was outside of the scope of the current study but could be evaluated in future.

5.8.2 **Hydraulic Connections Between Groundwater and Surface Water**

As components of the water cycle, the flow rates and availability of surface water and groundwater sources are often closely linked. For example, even during long periods of low precipitation many streams in coastal BC maintain year-round flows which are sustained by groundwater discharge (a.k.a. baseflow). Streams, lakes and wetlands can also contribute to groundwater recharge via infiltration and losses to the subsurface. The relationship between surface water and groundwater sources is complex and can vary both spatially and seasonally. For an overview of key concepts, refer to Winter et al (1998), Barlow and Leake (2012), and Woessner (2025).

Understanding and quantifying the mechanisms of interaction and hydraulic connection between surface sources such as lakes, rivers and wetlands, and groundwater aquifers is important to manage and protect water resources. In hydraulically connected systems, pumping of groundwater wells may influence conditions such as water level, flow, temperature, or water quality within nearby streams, lakes, rivers, creeks or wetlands. The effects may be felt rapidly or may take months to years to be observed. In the context of groundwater allocation and licensing, the potential for depletion of surface water sources resulting from groundwater use must be considered (Wei et al., 2016). Understanding hydraulic connectivity between surface and groundwater is also important when considering aquatic ecosystem requirements (referred to as Environmental Flow Needs or EFN), including water needed for maintenance of healthy aquatic habitats (Hatfield et al., 2004, 2003).

5.8.3 Seawater Intrusion Processes and Hazards

In coastal aquifers, such as on Cortes Island, fresh groundwater, which has a lower density than seawater, forms a freshwater lens that floats above the denser seawater around it (Bear et al., 1999). Beneath the Island, saline water circulates and extends inland from the coast forming a saline zone or wedge. Where the groundwater and ocean water come into contact is referred to as the freshwater-saltwater interface. A transition zone above this interface can contain a brackish mix of water from the two sources. The equilibrium between freshwater and seawater is maintained by groundwater that is recharged in higher elevation areas and discharges in lower elevation areas along the coast. The depth of the saline interface and transition zone fluctuates seasonally, depending on groundwater recharge and discharge, and can vary in response to tidal fluctuations and groundwater pumping. A conceptual diagram of a typical coastal island setting is shown in Figure 14.

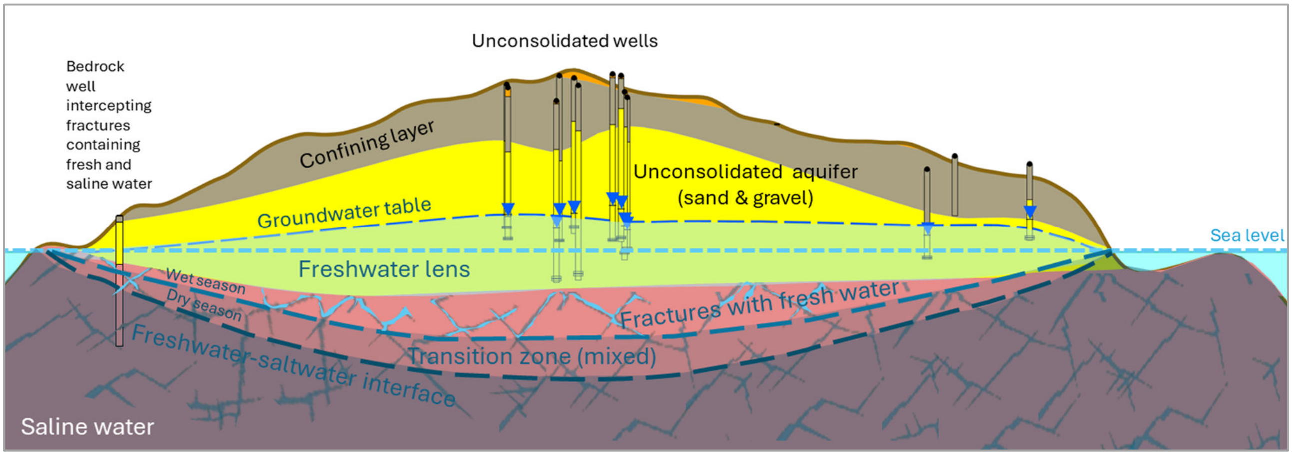


Figure 14. Cortes Island conceptual model of island setting illustrating freshwater lens and underlying transition zone to saline water

Seawater intrusion (SWI) refers to the change in groundwater quality that occurs from the mixing and movement of seawater into a freshwater aquifer. Sea water has roughly 35,000 mg/L total dissolved solids, including 19,000 mg/L chloride (US Geological Survey, 2000). Therefore, mixing in a very small quantity of sea water can significantly alter water quality in a freshwater aquifer. Mixing with 2% seawater can cause freshwater to taste noticeably salty (chloride 250 mg/L), while freshwater mixed with 4% seawater is unusable for most purposes (Klassen et al., 2014).

Aquifer vulnerability to SWI depends on multiple factors including topography, climate and hydrologic conditions and human activities (Werner et al., 2013). Human activities that may increase the hazard of seawater intrusion include drilling of deeper wells into the freshwater-saline water transition zone and interface, drilling of wells in bedrock aquifers that intersect fractures containing saline water, and over-pumping of one or multiple wells in vulnerable areas. Aquifers or areas that have a greater risk of seawater intrusion include:

- Aquifers located in low-lying areas close to the coast, on narrow islands or peninsulas with a limited up-gradient recharge area.
- Aquifers with groundwater level close to sea level.

- Coastal areas with a high density of wells or high rates of groundwater pumping.
- Wells where the static or pumping water level is close to or below sea level.
- Coastal areas where wells are drilled deeper intersecting the freshwater saltwater interface or saline fractures, allowing circulation and movement of water between saline and freshwater zones.

Climate change is expected to exacerbate existing sea water intrusion risk for islands in coastal BC (Klassen and Allen, 2016). For example, some areas will be inundated by rising sea levels. While storm surges are likely to overtop and flood lower elevation coastal zones. Changes in precipitation, higher temperatures, higher rates of evapotranspiration, and reduced groundwater recharge may alter the groundwater flux to discharge areas along the coast, enabling sea water to encroach further inland. If water demand and pumping increase in vulnerable areas, this can add further aquifer stress, therefore management of water demand is critical to protect coastal aquifers (Ferguson and Gleeson, 2012). Figure 15 illustrates some seawater intrusion processes and hazards for coastal areas and islands.

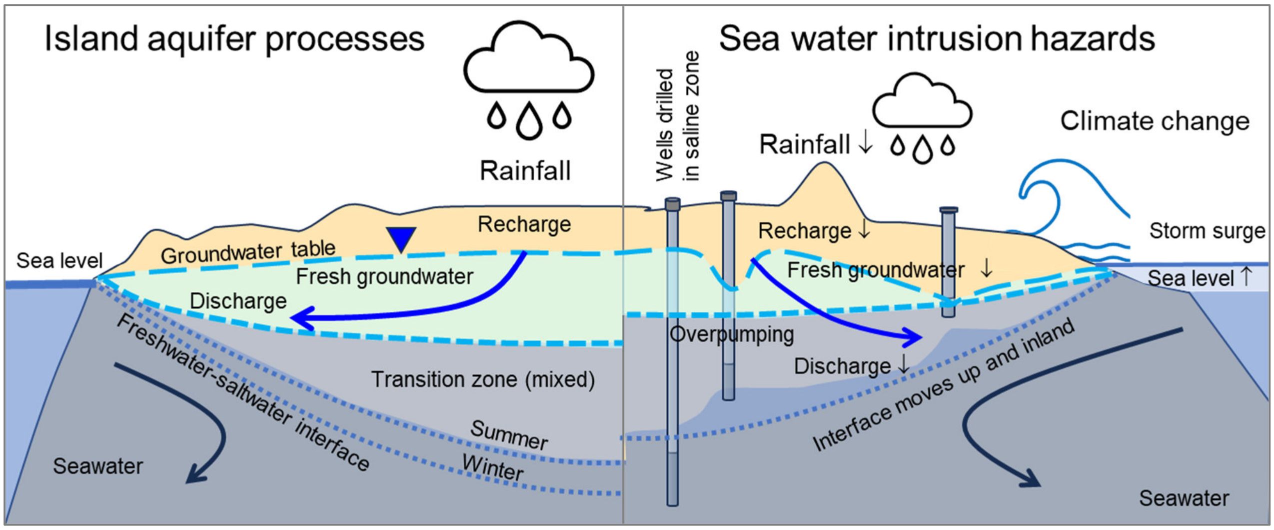


Figure 15. Seawater intrusion processes and hazards. After (Bear et al., 1999; Klassen and Allen, 2016; US Geological Survey, 2000).

The concentration of chloride, electrical conductivity and total dissolved solids (TDS) in a water sample can be used identify groundwater that is affected by SWI (Klassen et al., 2014). Groundwater from islands in BC's south coast is generally fresh. In the southern Gulf Islands, from a dataset of more than 900 groundwater samples, over 90% had a chloride (Cl) concentration below 150 mg/L, electrical conductivity (EC) below 1000 μS/cm and TDS below 700 mg/L (Klassen et al., 2014). These values have been recommended as SWI operational thresholds. If the concentration of chloride, TDS and EC go above the operational thresholds the reasons for the exceedance should be assessed and well operation, pump depth/pumping rate or other factors may need to be modified to prevent adverse impacts to water supplies from the subject well, the aquifer and other groundwater users. In a San Juan Islands study, wells with chloride concentration over 100 mg/L were considered impacted by SWI (US Geological Survey, 2000). Water quality guidelines and recommended operational thresholds are shown in Table 7.

SWI can cause permanent or long-term impacts on drinking water supplies, with adverse impacts on well operation and water use. For example, groundwater that is high in chloride and TDS is corrosive, potentially leading to deterioration and need to replace water fixtures more frequently. Drinking water with elevated chloride and sodium should be avoided for people with health conditions such as hypertension (Health Canada, 1992, 1987). While chlorine disinfection of water mixed with a marine or mixed source containing elevated bromide can lead to formation of harmful disinfection byproducts such as trihalomethanes (Health Canada, 2006).

Desalination, a technology used in areas of severely limited freshwater availability, is not an optimal solution for drinking water and household use. The treatment process is costly, utilizes a significant amount of energy and creates a concentrated saline brine that can cause environmental harm if not disposed of safely (Orfi et al., 2025). In areas with limited groundwater and surface water supplies, rainwater collection and storage is likely to be a more affordable and sustainable option compared to using desalination.

Table 7. Guidelines and operational thresholds for salinity indicators Total Dissolved Solids (TDS), Electrical Conductivity (EC) and chloride

	TDS	EC	Chloride	Notes
	mg/L	µS/cm	mg/L	
Guideline for Drinking Water Quality (Health Canada)	500	ng	250	Aesthetic objective. Concentration of chloride and Total Dissolved Solids (TDS) which causes a noticeable salty taste to the water. Drinking water with elevated chloride and sodium can be harmful to vulnerable persons with health conditions such as hypertension. Water with chloride and TDS above these values can also cause corrosion and scaling in pipes, water heaters and household appliances.
Ambient Water Quality Guideline for Irrigation (BC)	ng	ng	100	BC guideline based on potential impacts to more sensitive plant species. Some plant species may be adapted to irrigation with water with higher concentrations of chloride. Irrigating with water containing higher concentrations of dissolved minerals or ions (e.g. sodium, chloride, boron and nitrate) can reduce soil fertility and affect plant health.
Operational Threshold to Prevent Saltwater Intrusion	700	1000	150	Threshold indicates concentration significantly above the concentration in fresh groundwater sampled in coastal BC (concentration higher than 90th percentile of over 900 samples from aquifers the Vancouver Island and Gulf Islands Region). Because the thresholds are lower than the drinking water guideline, they are precautionary, indicating that well operation (or other factors) may be leading to deterioration of water quality in a well or aquifer.

TDS=Total Dissolved Solids EC=Electrical Conductivity or Specific Electrical Conductivity (adjusted to standard temperature) measured in field or lab ng=No guideline.
References: (Health Canada, 2024; Klassen et al., 2014; Province of BC, 2024).

6 WATER BALANCE MODEL

6.1 Gridded Water Balance Model Approach

A gridded water balance model was developed to assess groundwater availability on Cortes Island. The method involves estimating the different components of the water cycle to determine groundwater availability compared to water use. The gridded approach enables analysis of variable conditions over the island using a network of squares or pixels. The model inputs and outputs are based on a monthly time-period and summarized annually.

The water balance model inputs are climate-related parameters including precipitation, temperature, solar radiation and soil available water capacity. The model estimates how much water is available for evapotranspiration, compared to the amount anticipated to be lost to the atmosphere and used by plants. If there is a deficit, less water is available than will be lost to evapotranspiration, and no water is available for runoff or groundwater recharge. If a water surplus is available, this can contribute to runoff or groundwater recharge. The potential for infiltration to occur that will contribute to groundwater recharge is then estimated spatially, based on geology, soil, topography and other factors. Actual groundwater recharge is estimated and compared to water demand, determined based on the aquifer conceptual model and land use at the land parcel scale.

A flow chart representing the parameter inputs and outputs for development of the water balance model is shown in Figure 16.

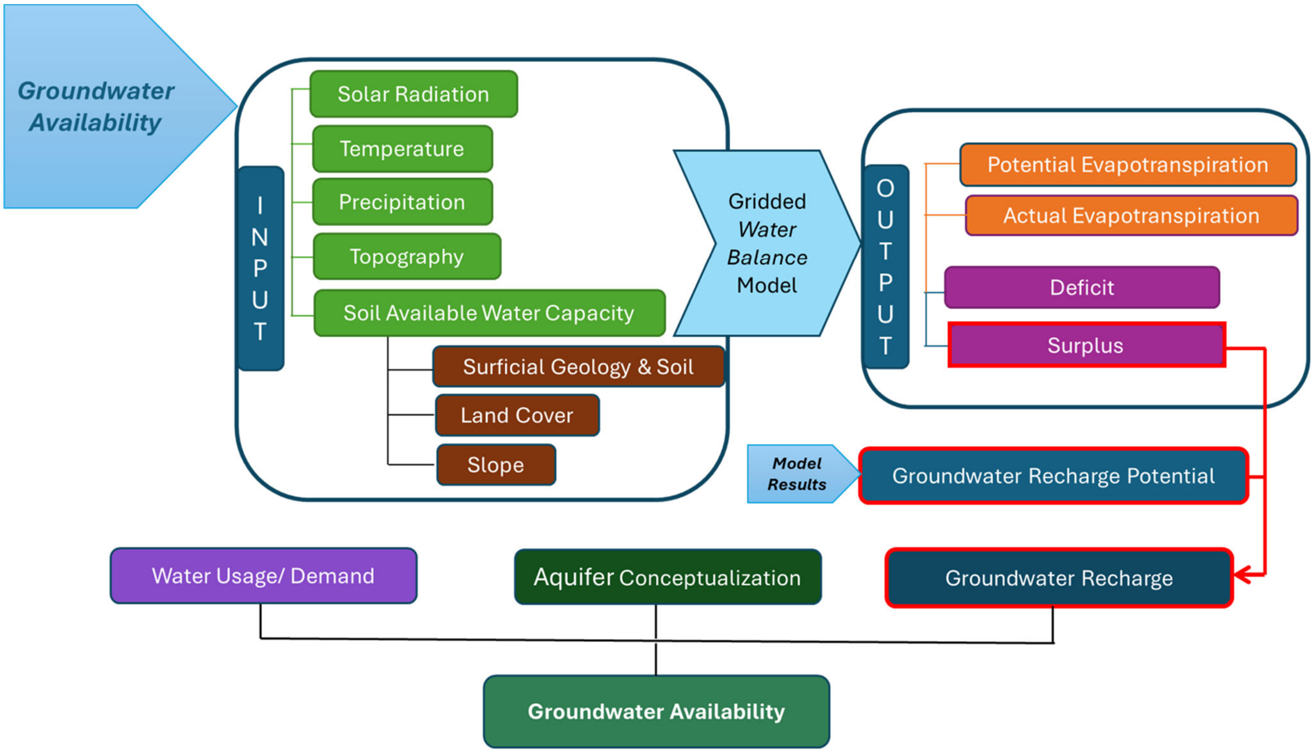


Figure 16. Water balance inputs and methodology to assess groundwater availability on Cortes Island.

6.2 Gridded Water Balance Model Methods

To estimate the water balance, the study used GW Solutions R-code implemented from the ArcGIS-based model developed by James Dyer from the University of Ohio (Dyer, 2021, 2019). The model estimates monthly potential evapotranspiration, soil moisture storage, actual evapotranspiration, soil moisture deficit, and soil moisture surplus using a grid-based, Thornthwaite-Mather approach (Steenhuis and van der Molen, 1986). The main data inputs include elevation, determined from a digital elevation model (DEM), soil available water capacity (AWC), monthly temperature (average), precipitation, and solar radiation. A 10 by 10 m pixel grid was used, based on the resolution of the digital elevation model.

The outputs of the model are:

- **Potential evapotranspiration (PE)** is estimated using the Turc Method. PE is the potential evaporative water loss from vegetation if water is not a limiting factor. PE depends mainly on heat and solar radiation.
- **Actual evapotranspiration (AE)** refers to water loss from vegetation given actual water availability from precipitation and soil moisture storage. If water is not a limiting factor, actual evapotranspiration is equal to potential evapotranspiration.
- **Deficit** represents moisture stress and occurs when the evaporative demand is not met by available water. In other words, it is the difference between potential and actual evapotranspiration.
- **Surplus** is excess water that is not evaporated or transpired. It leaves a site through runoff or subsurface flow or a combination of both. There can be no surplus if soil storage is not at full capacity.

6.2.1 Water Balance Model Logic and Assumptions

The Thornthwaite-Mather water balance method uses the following logic:

a) Precipitation minus potential evapotranspiration (P-PE):
    a. If supply from precipitation (P) < demand (PE), plants utilize soil water.
    b. If supply (P) > demand (PE), there is more water available than is needed by vegetation.
    c. Available water is prioritized as follows:
        i. Plants use what they need, first from precipitation, then from soil storage;
        ii. If there is still excess water, and the soil is not saturated, water is used to replenish soil storage;
        iii. Any excess water becomes surplus.

b) The calculation begins with soil water storage (ST) assumed to be full (equal to soil available water capacity (AWC)) based on consecutive values of P-PE. It can be assumed that soil storage is fully replenished if the sum of consecutive positive P-PE values exceeds AWC.

c) The change in storage (∆ST) from month to month depends on water use by plants (i.e., negative change in storage) or availability of excess water (positive change in storage).

d) Actual evapotranspiration (AE) is the actual amount of water used by plants or evaporated. If water is not limited, plants will use what they require for metabolic processes (AE=PE).

    a. Whenever storage (ST) = AWC, AE = PE (water comes from Precipitation (P)).
    b. As soil storage (ST) is depleted, it becomes increasingly difficult for plants to extract the water they need.
    c. When ST < AWC, AE = P + |∆ST|.

e) Water Deficit (D) = Potential Evapotranspiration (PE) – Actual Evapotranspiration (AE).

f) Surplus (S) is water left over after plant needs and soil storage are full. If ST is full (ST = AWC), there is expected to be “excess precipitation” if plants do not use it all.

    a. If ST < AWC, there can be no Surplus.
    b. If ST = AWC, then S = P - AE.
    c. Note that the month when ST equals AWC, S = P - AE - ∆ST (excess first goes to fill storage).

g) The balance in water supply and demand at a location can be expressed by two relationships:

    a. PE = AE + D (Moisture demand is equivalent to moisture transpired, plus the “shortfall.”).
    b. P = AE + S (precipitation is equal to actual evapotranspiration plus surplus not needed).

The above values are calculated for each month from January to December.

6.2.2 Data Inputs

Digital elevation model (DEM), aspect and slope

Slope and aspect (slope direction) rasters (gridded data) were derived from the 16-m resolution digital elevation model (DEM) (Natural Resources Canada, 2025a).

Soil Available Water Capacity (AWC)

Digital soil map layers were not available for Cortes Island. Soil characteristics were inferred from the surficial geology mapping and based on average values for soil types associated with similar surficial geology categories on Vancouver Island.

Important soil characteristics considered in the model included soil composition (mineral or organic), soil texture, coarse fragment content, drainage, soil layer thicknesses and characteristics, soil physical and chemical properties, as well as landform and parent material. Soil mapping also includes available water holding capacity at different depths (0.15, 0.30, 0.45, 0.60, 0.75, 0.90, 1.05 and 1.20 m). In temperate forests, 95% of root biomass occurs within the top 1 m of soil. Therefore, available water holding capacity at 0.90 m depth was used for the model input.

Geology (surficial geology, geomorphology)

Detailed surficial and Quaternary geologic mapping datasets were integrated in the model from various sources (Timberline Forest Inventory Consultants, 2006; Trettin, 2012a, 2012b; Trettin and Roddick, 2001).

Solar Radiation

Solar radiation was estimated based on topography (DEM), the geographic location and the time of the year. Solar radiation values (kJ m^{-2} day^{-1}) were obtained from WorldClim (http://worldclim.org/version2) at a resolution of 30 seconds (~1 km). The data were converted to watt-hours per square meter (Wh/m^2) per month for input to the model.

Average temperature and total precipitation

Gridded monthly total precipitation and maximum and minimum temperatures for Cortes Island were obtained from the Pacific Climate Impact Consortium (PCIC) (Pacific Climate Impacts Consortium, 2024). Two scenarios were utilized:

a) Environmental conditions based on climate normal data from 1981-2010. The climate model parameters were compared to monitoring data from the study area (e.g. Campbell River Climate Station EC1021261, the closest station with the most complete long-term dataset).

b) Climate conditions modelled for 2025 (the current year) based on the Shared Socio-economic Pathway SSP 2.6 from PCIC.

6.2.3 Gridded Water Balance Model Data Outputs

The initial water balance assessment includes the following outputs as gridded cells across the Cortes Island footprint (in mm):

Precipitation

Precipitation based on long-term climate normals and modelled current conditions (2025).

Estimation of Actual Evapotranspiration

Actual evapotranspiration based on potential losses and water availability from precipitation and soil storage.

Surplus (water that can contribute to runoff or groundwater recharge)

> Surplus is the remaining water (not evaporated or transpired) that leaves a site through runoff, infiltration into the subsurface, or a combination of both. There can be no surplus if soil storage is not at full capacity.

To estimate the actual recharge that will reach groundwater aquifers, the next step was to determine the groundwater recharge potential, which reflects the ability of water to infiltrate into the subsurface based on the topography and characteristics of geologic materials.

6.3 Groundwater recharge potential

The estimation of groundwater recharge potential considers slope, land cover, physiography and other factors which influence water infiltration and runoff. GW Solutions has developed a GIS-based methodology that incorporates both diffuse (spread over an area) and localized or focussed recharge pathways to estimate the spatial variability of potential recharge. The method uses infiltration or groundwater recharge coefficients for each of the spatial variables controlling recharge.

Across Cortes Island, *diffuse recharge* over a broad geographic area is inferred to be the dominant recharge mechanism in areas where thicker layers of unconsolidated materials overlay the bedrock. The percentage of precipitation that contributes to diffuse recharge is dependent on factors such as the drainage capacity of the soil, land cover type, local topography or slope, and the depth to the water table. Concentration of runoff contributing to *focused recharge* into unconsolidated aquifers is also expected to occur in localized physiographic features such as roadside swales, natural depressions, gulleys, and gorges observed in forested areas of the island.

In comparison, *focused recharge* via discrete bedrock features is the main recharge mechanism in areas where the overburden is thin or bedrock is exposed. Large-scale linear features or lineaments, which are be identified from air photos or satellite imagery, can indicate the potential location of geologic features such as fractures, faults and bedding planes, or contacts between different geologic units. Groundwater recharge and flow within the fractured bedrock system depends on the width, length, openness, storage capacity, inter-connectivity and transmissivity (hydraulic conductivity across an aquifer cross-section) of the bedrock fracture networks.

Across Cortes Island, there are also surface water features such as lakes or creeks that interact with the groundwater system. For example, lakes and streams may potentially receive groundwater discharge from deeper regional flow systems that are fed from infiltration on upland bedrock slopes, referred to as mountain block recharge (MBR). Conversely beneath or adjacent to surface water bodies such as lakes, wetlands and streams, diffuse or focused recharge may occur into underlaying or adjacent unconsolidated quaternary sediments or bedrock formations. Seepage and infiltration from surface sources depend on hydraulic gradients, and the thickness and permeability of the underlying sediments (i.e. presence of lower permeability clay, silt or till deposits). The potential interaction between surface and groundwater systems on Cortes Island is not well understood at this time, in part due to the lack of monitoring data.

6.3.1 **Methods and assumptions**

Groundwater recharge potential (GRP) was determined in QGIS by developing a raster grid which estimates the relative capacity of each area to intercept and infiltrate precipitation. The GRP estimation combines the values of different deterministic or conditional factors- such as elevation, slope, drainage capacity of surficial sediments and fractured bedrock, land cover, geomorphology, and depth to groundwater that influence how precipitation which is received on the landscape, either runs off or infiltrates and percolates into the ground. The data sources, key deterministic factors and their relative weighting have been adapted from previous studies in the southern Gulf Islands, northern Gulf Islands, District of Highlands, and Savary Island (GW Solutions Inc, 2021, 2023, 2022, 2024), further enhanced by developing and running multiple scenarios for Cortes Island. A process diagram outlining the input factors utilized to determine the GRP for Cortes Island is included in Figure 17. The conditioning factors were classified, normalized and processed in QGIS using a weighting approach. Weighting factors were determined based on previous studies and the main factors predicted to influence groundwater recharged across Cortes Island.

6.3.1.1 *Unconsolidated and fracture bedrock geologic domains*

The recharge mechanisms and the values of conditional factors are different for the unconsolidated materials (porous media) compared to bedrock (fractured bedrock) therefore two different approaches were developed to estimate the groundwater recharge potential within the two different domains on the island. The unconsolidated domain was delineated and separated from the bedrock domain based on the boundary of Quaternary sediments in geologic map layers (Trettin, 2012b) and the overburden thickness, one of the Leapfrog model outputs derived from analysis of well construction records. These two domains are shown in Figure 18A.

6.3.1.2 *Land Cover Coefficient (0- 0.9)*

Vegetation affects groundwater recharge through the interception of precipitation by foliage and use of water for plant growth (i.e., transpiration). Greater foliage interception also leads to longer exposure to the atmosphere and increased evaporation. In comparison, cleared and unpaved areas have less transpiration and evaporation and thus promote greater water infiltration.

A landcover raster dataset with a 30-meter resolution was obtained from NRCAN (Natural Resources Canada, 2025b), and further validated using satellite imagery to identify urbanized areas (houses, roads), croplands and bare lands. The raster resolution was reformatted to a 10-meter resolution. Table 8 summarizes the assumed weighting factor for infiltration based on the type of landcover/land use. The resulting map is shown in Figure 18B.

Table 8: Groundwater Recharge Potential based on landcover type and infiltration coefficient

Groundwater Recharge Potential	Land Cover Type	Infiltration coefficient
Very low	Temperate or sub-polar needle leaf forest	0.3
	Temperate or subpolar deciduous forest subpolar	
	Temperate or sub-polar shrubland	
Low	Temperate or sub-polar grassland	0.4
Moderate	Cropland	0.7
High	Urban	0.8
Very high	Barren lands	0.9
None	Water	0

6.3.1.3 *Preferential recharge/discharge areas (PRDA) (0 - 1)*

Within the water cycle, a proportion of precipitation received at the ground surface will infiltrate into the ground creating groundwater recharge. Groundwater recharge typically occurs in upland areas where the unsaturated zone is thicker and the depth to the groundwater table is deeper, allowing water to percolate underground and replenish the aquifer. In contrast, groundwater discharge areas are typically located in topographic lows such as along streams, valleys and shorelines, providing seasonal or year-round baseflow to streams, wetlands and springs (Fetter, 2018).

The depth of the groundwater table or the thickness of the unsaturated zone has a significant role in controlling groundwater recharge rate across Cortes Island. Despite surficial materials and/or exposed fractured bedrock that are suitable for groundwater infiltration, a shallow water table limits the amount of water that can infiltrate into the ground.

The two factors “average interpreted groundwater elevation” and “depth to water” were used to estimate the potential for groundwater recharge to occur. For instance, if the groundwater level is above the ground surface, it indicates a groundwater discharge zone, in which groundwater recharge will be limited. The opposite condition is observed when the groundwater level is below ground and allows mostly groundwater recharge to occur.

Groundwater depth measurements collected by well drillers at the time of well construction were obtained from records in the GWELLS database. These values reflect groundwater conditions during different seasons, and over many years, but are considered sufficiently representative at the regional, composite scale.

Using the Leapfrog model a groundwater elevation surface was created (groundwater elevation grid in meters above sea level) and exported into QGIS as a raster file. The interpreted depth to water across the island was generated in QGIS by subtracting the average interpreted groundwater elevation from the gridded topographic elevation using Digital Elevation Model (DEM).

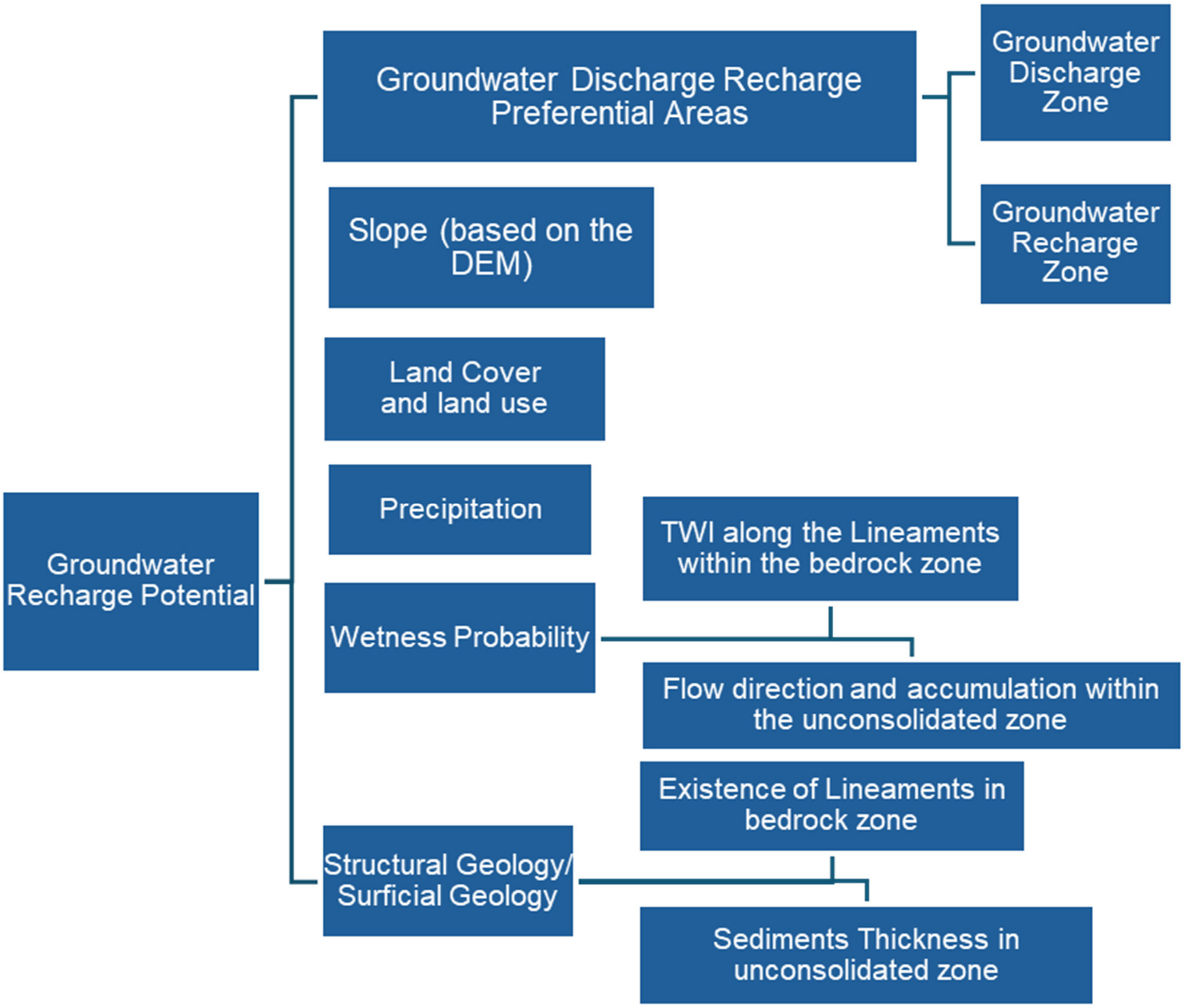


Figure 17: Flow chart illustrating the inputs used to estimate the groundwater recharge potential.

There are no Provincial Observation Wells (OW's) on Cortes Island to measure seasonal groundwater fluctuations over within the unconsolidated (4b) and fractured bedrock (6b) aquifer subtypes. It was assumed that the annual range in aquifer water levels is similar to ambient groundwater levels in aquifers of the same or similar subtype (e.g. Observation Well OW204 in AQ608 fractured granitic bedrock aquifer, in Saanich, Vancouver Island, or OW383 in AQ834, a 4b Quadra sand aquifer on Quadra Island (Ministry of Environment and Parks, 2025b). Annual groundwater levels may fluctuate by 6 meters or more in the fractured bedrock domain, or by less than 1 meter in unconsolidated domain. In coastal BC, shallower groundwater levels are observed in late winter/early spring and deeper levels are observed in late summer/early fall (Wei et al., 2009). In coastal areas tidal fluctuations can also influence daily and seasonal groundwater level observations (Klassen and Allen, 2016). For this study, all areas identified with either permanent or seasonal groundwater discharge, where the average interpreted depth to water is less than 6 m in fractured bedrock zone and less than 1 m in unconsolidated media were classified as groundwater discharge areas.

Maps of preferential recharge and discharge areas in both the fractured bedrock and unconsolidated domains were developed based on the average interpreted groundwater across the island. An attribute rating system was developed and assigned with a higher value to a probable groundwater recharge area, with the highest value of “1”, and the less value to a probable groundwater discharge area, with minimum value “0”. Figure 18C illustrates the map of preferential recharge and discharge areas.

6.3.1.4 *Slope Coefficient (0-1)*

Topography greatly influences the potential for water infiltration to the subsurface. In groundwater recharge areas, a flat or shallow slope promotes infiltration, whereas a steep slope promotes runoff and decreases infiltration. The digital elevation model with 16 meter resolution (Natural Resources Canada, 2025a) was processed to generate the topographic slope with a 10 m resolution. The topographic slope (in degrees) was classified into seven categories representing high to low groundwater recharge potential. The resulting slope infiltration factors are summarized in Table 9 and shown in Figure 18D.

Table 9: Groundwater recharge potential and infiltration factors depending on slope.

Groundwater recharge Potential	Slope (degrees)	Infiltration coefficient
No chance of recharge	>45	0
Lowest	20-45	0.1
Very low	12-20	0.2
low	8-12	0.3
Moderate	5-8	0.5
High	3-5	0.75
Very high	<3	1

6.3.1.5 *Precipitation Coefficient (0.92-1.0)*

Precipitation is a primary factor influencing groundwater recharge. There is higher chance of groundwater recharge in areas where precipitation is high.

The distribution of precipitation across a region is spatially variable, and influenced by multiple factors such as latitude, altitude or elevation, distance from the ocean, and atmospheric patterns. To capture these factors in the groundwater recharge potential mapping, a gridded annual total precipitation dataset, based on climate normals for the

1981-2010 period, was used to generate an infiltration coefficient for different areas of the island. Gridded precipitation data downloaded from the ClimateBC. Table 10 presents the infiltration coefficient based on the range of precipitation mapped across the island and Figure 19E shows the data spatially.

Table 10: Precipitation infiltration factors and groundwater recharge potential based on annual average (climate normals 1981-2010).

Groundwater Recharge Potential	Precipitation range (mm)	Infiltration coefficient
Low	1270-1420	0.92
Moderate	1420-1560	0.96
Good	1560-1700	1.00

6.3.1.6 *Wetness Coefficients*

The topographic wetness coefficient is a measure of the probability of water drainage at a site, based on the slope and surficial geology (Nguyen Ngoc Thanh et al., 2022). Areas with a higher wetness coefficient are more likely to capture runoff from a larger area, compared to areas with a low wetness coefficient where drainage is unlikely.

To generate the wetness coefficient, a Flow Direction and Accumulation (FDA) layer was created for the unconsolidated domains across the island using QGIS tools. For the fractured bedrock domain, the Topographic Wetness Index (TWI) was generated based on mapped linear features. Table 11 summarizes the assumed weighting factors for infiltration based on the value range of FDA and TWI. Large values for FDA and TWI are typically associated with lowlands having a larger contributing (catchment) area. Figure 19F, shows the relative probability of accumulated flow percolating into the ground within the fractured bedrock domain and the unconsolidated formations across the island.

Table 11: Groundwater Recharge Potential and Infiltration Coefficient based on Flow Direction and Accumulation (FDA) and Topographic Wetness Index (TWI)

Groundwater Recharge Potential	TWI and FDA Range	Infiltration Coefficient
Lowest	<3	0
Low	3.0-4.0	0.4
Moderate	4.0-6.0	0.6
High	6.0-8	0.8
Very High	> 8	1

6.3.1.7 *Surficial Geology and Structural Geology*

To calculate groundwater recharge potential across the island, the overburden or sediment thickness and extent influences recharge potential in unconsolidated domains, whereas the presence and exposure of linear geologic structures (faults, fracture zones, geologic contacts) is an influential factor in bedrock domains.

Surficial geology

Surficial geology refers to properties and characteristics of unconsolidated (loose) sediments that overlie bedrock. The size of the sedimentary particles, their thickness, their compaction and how the sediments are stratified or layered defines the soil structure. These characteristics, along with pore saturation and capillary forces, influence the ability of soil or surficial sediments to absorb and hold water during rainfall events and contribute to groundwater recharge (Christelle Basset et al., 2022).

Characteristics of unconsolidated materials, and their thickness and extent across the island were determined from various sources including GWELLS records (Province of BC, 2025a) incorporated into the hydrostratigraphic model (discussed in section 5.1), and historical geologic mapping of the Cortes Island (Talisman Projects Inc., 1979a, 1979b; Timberline Forest Inventory Consultants, 2006; Trettin, 2012b; Trettin and Roddick, 2001).

A weighting infiltration factor (groundwater recharge coefficient) was determined based on the thickness of sediments within the delineated unconsolidated domain. Table 12 summarizes the unconsolidated thickness infiltration factors that were combined with the previously described preferential groundwater recharge and discharge mapping (PRD) to determine the groundwater recharge potential in the unconsolidated domain, shown in Figure 19G. Areas with thicker sediments suggest a higher probability for groundwater recharge.

Table 12: Sediments thickness and groundwater recharge factor for unconsolidated domain

Sediment Thickness (m)	Groundwater Recharge Coefficient (Probability of forming aquifers)
0-10	0.5
10-30	0.6
20-30	0.7
30-60	0.8
60-90	0.9
>90	1

Structural geology

The locations of major linear geologic features or lineaments were delineated based on the DEM, bedrock geology mapping and BC mapping of faults and geologic contacts (Cui et al., 2019; Natural Resources Canada, 2025a; Trettin, 2012a). The resulting dataset was validated using satellite imagery to exclude features associated with human structures such as roads. Mapped lineaments are show in Figure 19H.

Depending on their location and characteristics, some lineaments could potentially contribute to groundwater recharge, while others are likely locations of groundwater discharge. The depth to groundwater (output from Leapfrog Model) was used to differentiate the probable function of each geological feature in groundwater recharge.

Mapped lineaments were combined with Topography Wetness Index (TWI) to estimate the recharge potential along each lineament. The infiltration factor was considered 0 for areas within the bedrock domain with no lineament present.

6.3.1.8 *Groundwater recharge potential calculation*

Across Cortes Island the composite groundwater recharge potential was determined using two different equations for either the unconsolidated or bedrock domains using the following equations.

For Bedrock Zone

$$RP=R_{PRDA}\,[\,20\%\,(R_{\text{Landcover}}) + 25\%\,(R_{\text{Precipitation}}) + 25\%\,(R_{\text{Slope}}) +30\%\,(R_{\text{TWI along Lineaments}})]$$

For Unconsolidated Zone

$$RP= R_{PRDA} * R_{\text{thickness}}\,[\,30\%\,(R_{\text{Landcover}}) + 25\%\,(R_{\text{Precipitation}}) + 25\%\,(R_{\text{Slope}}) +20\%\,(R_{\text{FDA across the surficial sediments}})]$$

where:

RP = Recharge potential (0-100%)
R_{PRDA} Factor = Preferential Recharge/Discharge Areas Factor (0-1)
$R_{\text{Land cover}}$ Coefficient= Land Cover/ Land Use Factor, Influence ranges up to 25% in Bedrock zone and 30% in Unconsolidated materials zone
R_{Wetness} Coefficient = Flow Direction, Accumulation and Topography Wetness Index, Influence ranges up to 30% in Bedrock zone and 20% in Unconsolidated materials zone
R_{Slope} Coefficient = Slope Factor; Influence ranges up to 25%
$R_{\text{Precipitation}}$ Coefficient= Precipitation Factor, Influence ranges up to 25%
$R_{\text{thickness}}$ Factor= Thickness of Unconsolidated Material Factor

6.3.2 Groundwater Recharge Potential Results and Discussion

The resulting groundwater recharge potential map for the Island is presented in Figure 20. The highest groundwater recharge potential of 1 suggests a very high potential for recharge, across a flat (zero slope) bare land (non-vegetated) within surficial geology material of sand found within areas with a high preferential of recharge (PRDA=1). The lowest recharge potential values are typical for areas of preferential groundwater discharge (PRDA=0). Groundwater recharge potential across Cortes Island varies depending on the location. Slope, surficial and structural geology have the greatest influence on whether precipitation will infiltrate into the sub-surface. In general, diffuse recharge is anticipated to occur across most of the areas where there are unconsolidated surficial materials. Localized recharge can occur along discrete, bedrock lineaments (fractures, faults and geologic bedding planes and contacts) where there are a bedrock outcrops. Cliffsides, beaches and lower elevation planes along the margins of the Island, and in the locations of surface water features such as lakes have a lower recharge potential and are considered discharge zones.

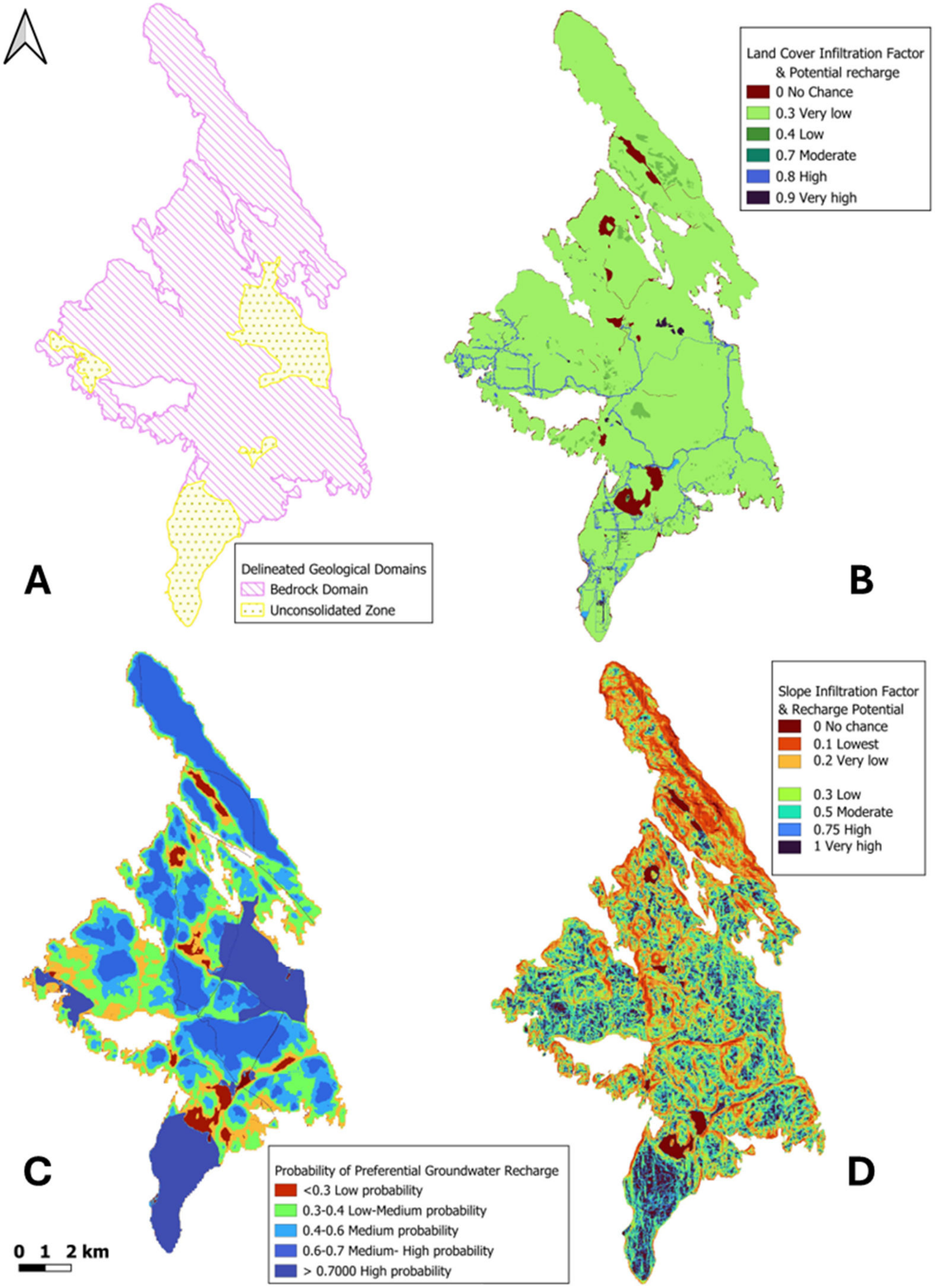


Figure 18: Input layers to calculate groundwater recharge potential A) geological domains, B) land cover infiltration factor, C) probability of preferential groundwater recharge, and D) slope infiltration factor.

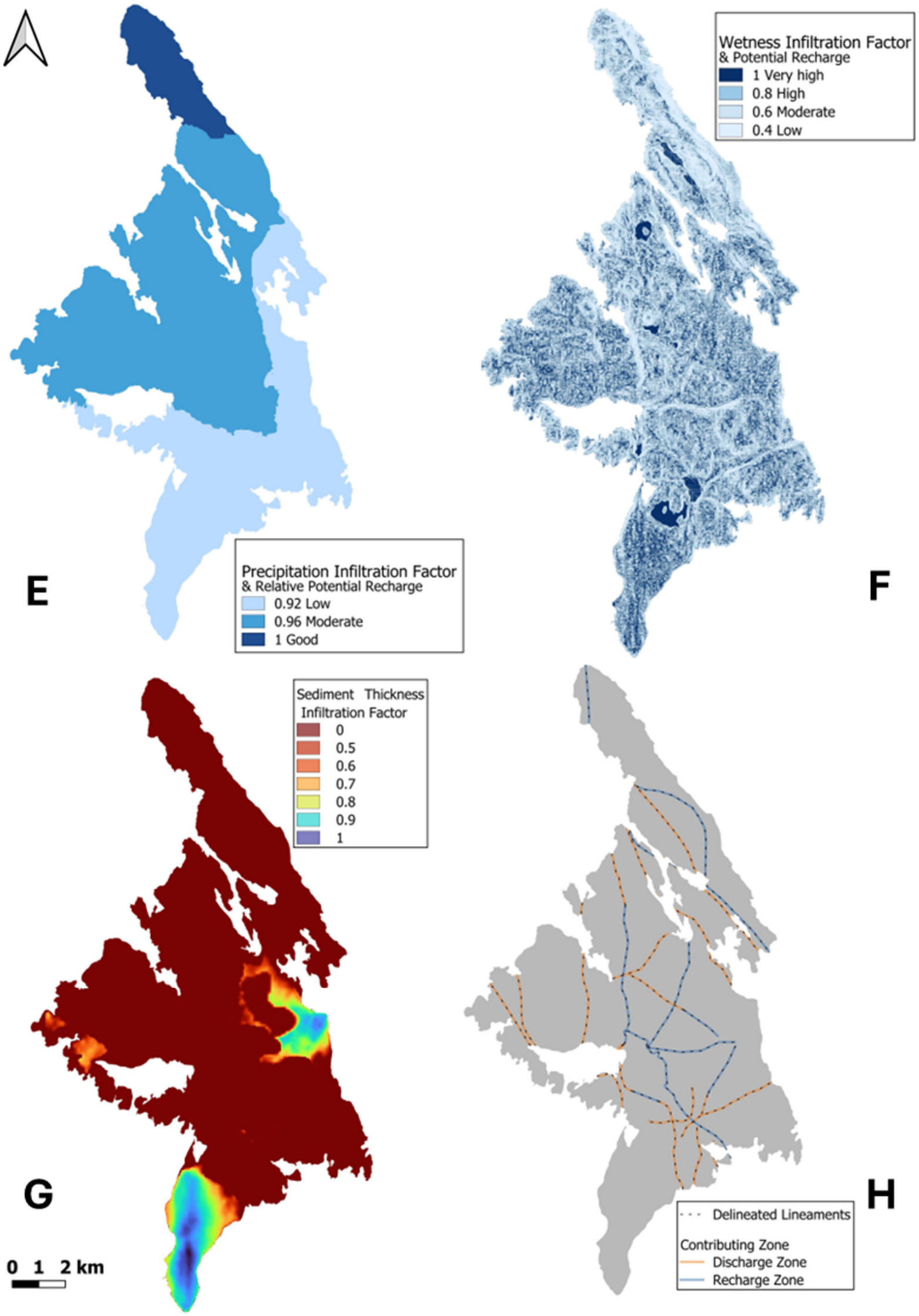


Figure 19: Input layers to calculate groundwater recharge potential E) precipitation infiltration factor, F) wetness infiltration factor, G) sediment thickness infiltration factor, H) delineated lineaments.

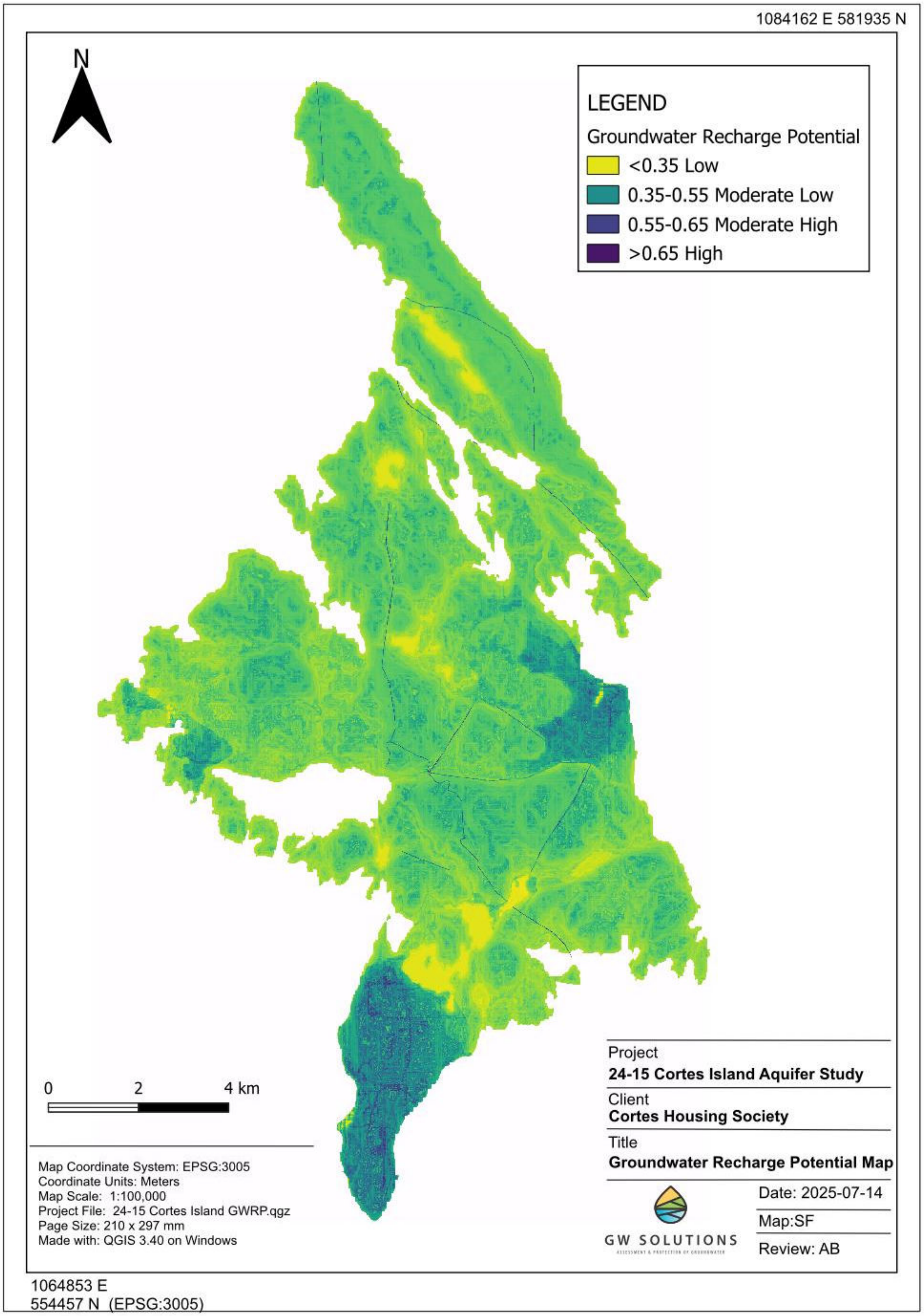


Figure 20: Groundwater recharge potential.

6.4 Water Demand

Development of the water balance model requires and estimation of water demand compared to water availability. Accurate estimation of water use is particularly challenging in rural areas where water is supplied from independent, typically un-metered, water sources such as domestic wells, and on islands with significant seasonal differences in population.

Water demand was estimated based on land use, zoning and occupancy at the parcel level, combined with information on registered wells, surface and groundwater licenses, local directories, and personal information provided by well and property owners. A flow chart showing the general approach for estimating water source and demand for each parcel is outlined in Figure 21. The assumptions, methods and resulting estimates of water use on the Island are discussed in the sections below.

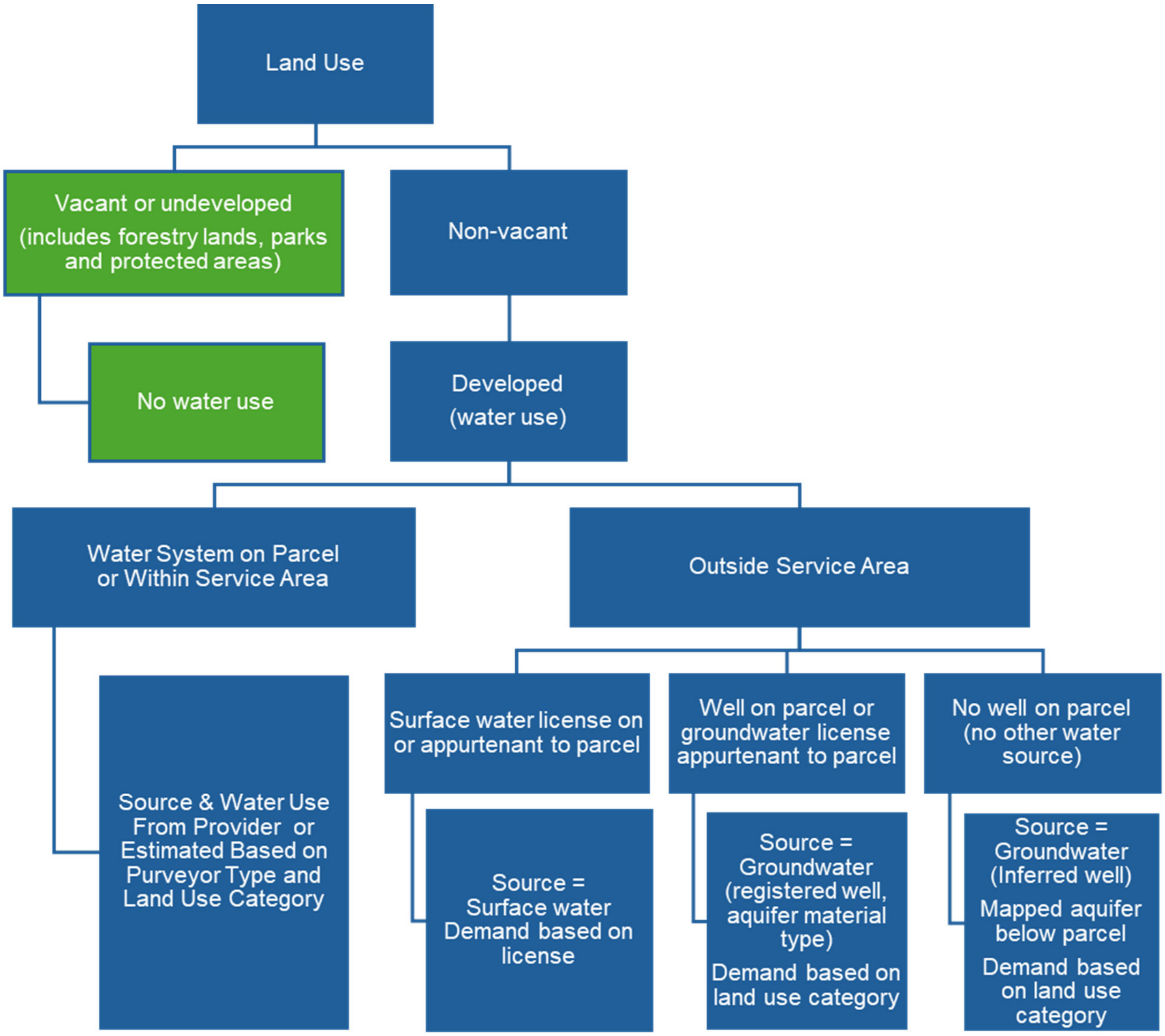


Figure 21: Determination of water demand from land use.

6.4.1 Population and Seasonal Occupancy

The Cortes Island population is roughly 1,120 persons (Table 13), based on the most recent Canadian census, with around three-quarters considered full-time residents (Statistics Canada, 2023b). The population approximately doubles in summer, with the addition of part-time residents, seasonal workers, and tourists (Strathcona Community Health Network, 2019).

Table 13: Cortes Island population.

Location or community	Population			Total private dwellings 2021	Private dwellings occupied by usual residents 2021	Dwellings occupied by usual residents (Note 5)	Note
	2021	2016	Change 2016 to 2021				
Strathcona Regional District (SRD) Area B, Cortes Island	1,059	1,035	+2.3%	804	558	69%	1
Manson's Landing	158	149	+6%	111	85	77%	1
Klahoose First Nation (Tork 7 Reserve, Squirrel Cove)	60	64	-6.3%	42	33	79%	1,2
Total SRD Area B plus Klahoose (Tork 7)	1,119	1,099	-2%	846	591	70%	
Estimated summer population (daily)	3000	Estimated population increase in summer			1.7%		3,4

Notes and referenced sources: 1. Census Profile, 2021 (Statistics Canada, 2023b). 2. Current population of Klahoose First Nation higher than federal census, reported as approximately 70 full-time residents and 120 residents in summer (Robert Dinning, Klahoose First Nation, Infrastructure and Development Manager, personal communication, May 23, 2025.) 3. Social Determinants of Health Fact Sheet: Cortes Island (Strathcona Community Health Network, 2019). 4. Percent seasonal difference calculated from census and Health Network study values. 5. "Usual residents" interpreted as full-time occupancy (living on the island greater than 6 months per year).

6.4.2 Water Service Areas and Water Systems

Twenty-two water systems were identified from data layers provided by Island Health (Island Health, 2020), published Drinking Water Reports and Summaries (Island Health, 2025), island directories and local contacts. All of the inventoried water systems utilize a groundwater source. Most of these provide water to a single parcel or small number of adjacent parcels.

There are two neighbourhood-scale water systems. The Whaletown Water System is located on the east side of Whaletown Bay and has 17 connections. The Klahoose First Nation operates a water system that provides water to the Klahoose community on Tork Road which currently serves up to 120 residents. Service areas associated with these water systems were mapped and water use on lots within the boundary were assumed to be provided by the community supplier.

6.4.3 Measured Water Use

Most water users do not monitor or record their water usage, although some water systems use water meters. Short-term (daily, seasonal) water use amounts were provided by a small number of water systems which were used to help inform the understanding of local usage patterns. Example values provided by Whaletown Water System, which services 17 connections, are shown in Table 14 below. Long-term metered water usage data were not available for analysis, therefore water demand was estimated using proxy values from other areas, or empirically estimated from literature references as described further below.

Table 14: Whaletown Water System reported water usage (example values).

Period	L/connection/day
Winter (2024)	588
May (2024)	647
June (2024)	3353
Median	647
Parcel occupancy (%)	
Year-round	71%
Seasonal	29%

Reference: Christine Robinson, personal communication, May 22, 2025. Values represent bulk metering from source and may include losses due to leakage.

6.4.4 Land Use

The primary sources of data included information on land use, and occupancy from BC Assessment Primary Actual Land Use categorization for the 2025 Assessment Roll Year (BC Assessment, 2025). A spatialized data layer was provided by the Strathcona Regional District GIS department, indicating a code and description of land use individual land parcels (cadastral lots). Land use categorization was not provided for all areas of the island, such as for some forestry designated Crown lands on north Cortes, Federal Crown and First Nations treaty and reserve lands. Additional land use layers, including BC Parks, Ecological Reserves and Protected Areas were obtained from the BC Data Catalogue (BC Data Catalogue, 2025).

The land use categories were used to estimate water demand per developed lot for the designated land use. Figure 22 shows a map of actual land use on Cortes Island grouped into major categories including residential, commercial, industrial, farm and managed forest.

The larges land use by area is primarily residential including single family, and acreages (large lots of 2 acres or more). For lots within a defined Actual Use category, a total of 153 parcels were classified as Vacant, with a total area of 25 km^2 representing 20% of the classified parcels by area. Vacant parcels have no associated water demand but could be developed in future.

Table 15: Actual Land Use Group Categories and Area.

Actual Use Group Category	Count	Area (km^2)	%
Acreage	606	54.9	44%
Undefined*	222	52.7	42%
Forest Use	26	13.5	11%
Farm	14	1.8	1%
Civic-Recreational	15	1.8	1%
Single Family Residential	166	0.8	1%
Commercial	17	0.3	0.2%
Multi-Family	3	0.2	0.2%
Utility	8	0.04	0.03%
Industry	2	0.04	0.03%
Grand Total	1079	126.1	100%

*Includes managed forest and Provincial Crown Lands (dataset does not include entire island.

6.4.5 Water Source

The water sources for the land parcels were assigned to one of four categories listed in Table 16 and shown in Figure 23, based on review of active water licenses and water license applications, water license works, registered wells, and water system inspections reports (Island Health, 2025; Province of BC, 2025a; Water Management, 2025b, 2025a). Parcel water sources were also validated by satellite imagery to identify property development status, and information provided by local contacts and landowners via email or during field visits in May 2025.

The greatest source of uncertainty is within the assumed groundwater use category. There are 389 parcels in the subdivision parcel class which were assumed to be utilizing a groundwater source (developed lot with no registered onsite well, and no other identified water source). These lots may be using an unregistered well, or an unlicensed surface water source. To improve accuracy of the water balance assessment and identification of parcel water sources, property owners should be encouraged to register their wells, and neighbourhood well inventory programs could be completed.

Table 16: Water source categories.

Water source	Parcel criteria and description	Code	Number of parcels	% Parcels
No water use	Actual land use is vacant (undeveloped) Parks and protected areas (except parks with camping facilities) No water system source on parcel Not within a water service area Includes roads and Crown parcels with undefined Actual Use	0	363	34%
Surface water source	Surface water license on or appurtenant to parcel Water license works terminate on parcel (i.e., mapped infrastructure) Parcels bordering large lakes (e.g. Hague Lake) with no onsite well	1	96	9%
Groundwater source	Registered onsite well	2	186	17%
Surface plus groundwater use	Surface water license appurtenant to parcel Groundwater source (well) on parcel	3	20	2%
Groundwater source (assumed)	Lot is developed (non-vacant) No well or surface water license on or appurtenant to parcel Not within a service area	4	414	38%
	Total		1079	100%

Notes: North Cortes Island not included in spatial dataset.

6.4.6 Groundwater Use per Actual Land Use Category

Groundwater demand for Cortes Island was estimated at a monthly time step, considering local and seasonal patterns of land use, water use and occupancy. Groundwater demand was determined for the island, for aquifers and for management areas of interest including the Manson’s Landing, Whaletown and Squirrel Cove areas. The general approach for each water use or land use purpose is outlined below. Additional tables and references are included in Appendix C.

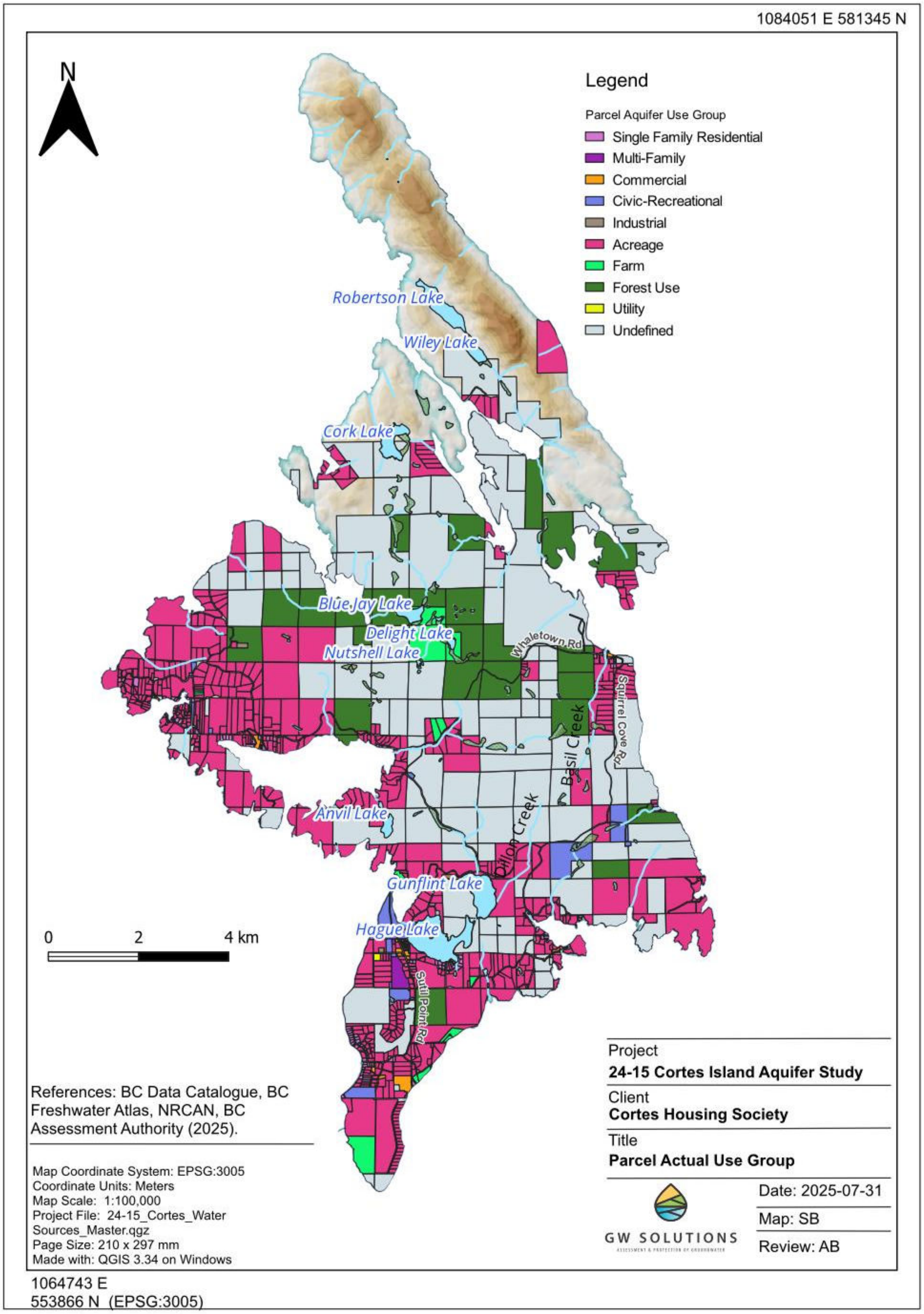


Figure 22: Cortes Island parcel Actual Land Use by category group.

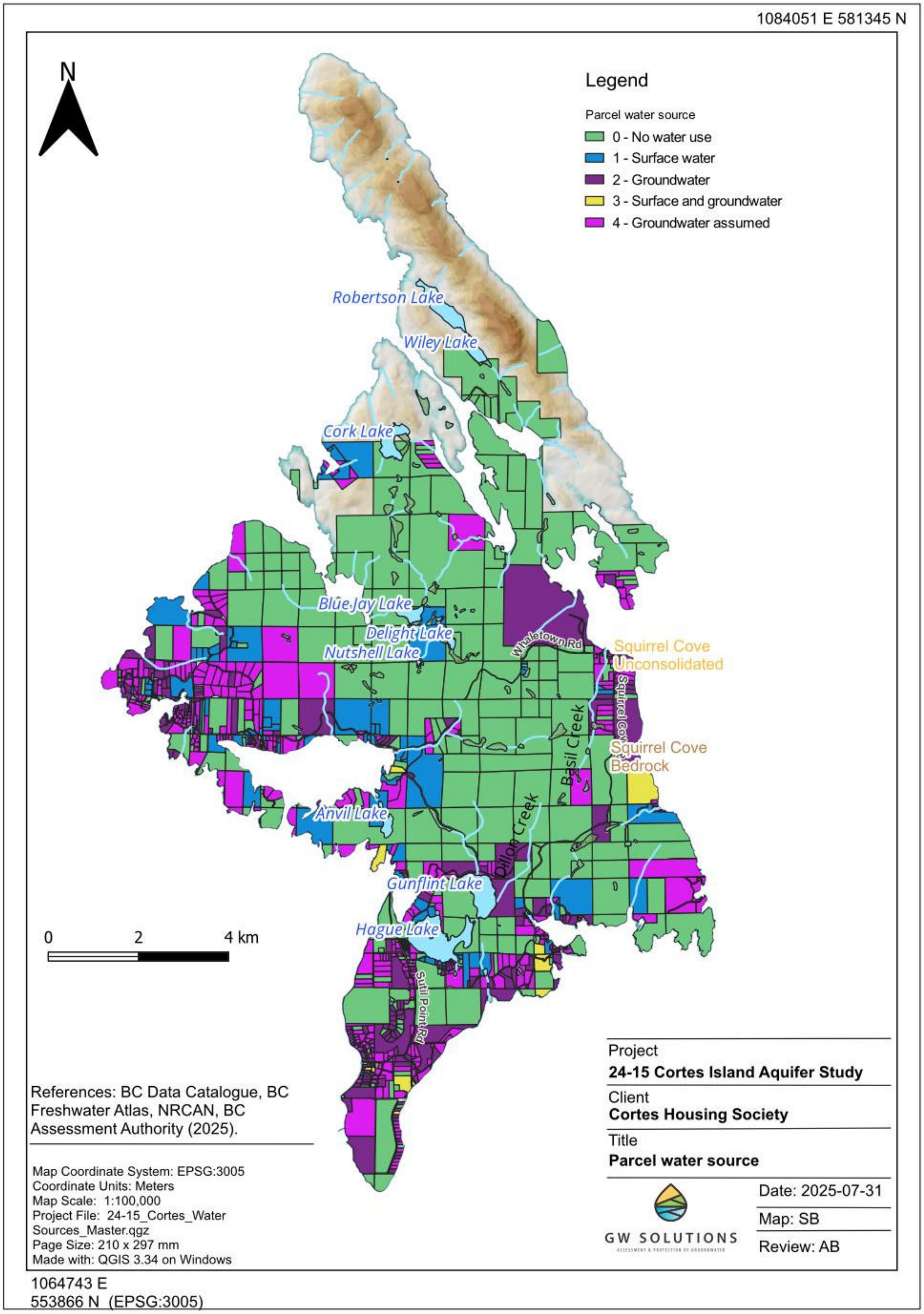


Figure 23: Cortes Island parcel water source.

Residential (Acreage, Single Family and Multi-Family): Monthly residential water use per parcel was estimated based on local information, and representative values from other communities. Long-term metered water use data were evaluated from representative groundwater sourced water systems in Regional District of Nanaimo and compared to national census values for BC. Categories of residential use per parcel were developed based on parcel size and residential use category. Figure 24 shows the estimated daily water use per connection in each month for R1 and R2 residential water use categories. Higher water use (R2) was assigned to parcels of 2 acres or more; this is to account for larger potential irrigation area and outdoor water use for gardens, and likelihood of larger homes or multiple habitations to be constructed on larger parcels. Residential peaking factors were developed based on monthly water use estimates. Seasonal dwellings were assigned monthly seasonal peaking factors which accounted for reduced water use during the off-season (winter). Multi-family units or parcels (RU) were assigned water use according to the low water use residential category (R1) multiplied by the number of housing units e.g., duplex (2), or multi-unit strata lots. The category “Residential, outbuilding only” was also assumed to be occupied by a residence or building that utilized water (R1). Unless specified within the land use category (e.g. residential dwelling with suite), only one residence was assumed per parcel, although it is known that some parcels have multiple dwellings.

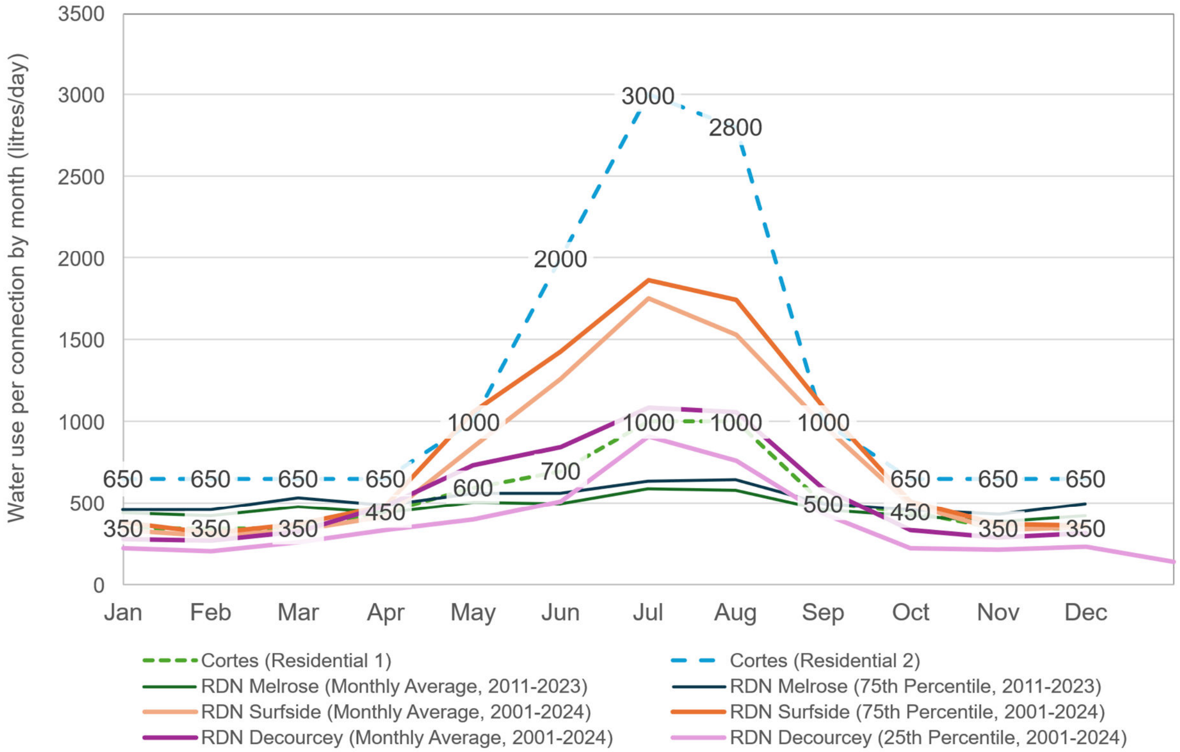


Figure 24: Cortes Residential 1 (R1) and Residential 2 (R2) Water Use Categories compared to representative values from Regional District of Nanaimo long-term metered use (groundwater supplied water systems).

Agriculture and Mixed Use: A desktop review of satellite imagery of representative agricultural parcels was completed estimate irrigation demand using the Agricultural Water Use Calculator (Ministry of Agriculture and Food, 2025). Based on the reviewed parcels, approximately 10% of each agricultural parcel was assumed to be irrigated. Example values of water use per month were used to develop irrigation volume per inferred crop type (e.g. vegetable and fruit vs forage) per parcel irrigated area, and to develop monthly peaking factors for the irrigation season, which were applied from May to September. All non-vacant mixed-use parcels in the agricultural category were also assigned a residential (R1) water demand to account for water use in onsite residences. Additional values for livestock parcels (e.g. “Poultry” were based on parcel size and reference values (Miles, 2009; Ministry of Agriculture and Food, 2025).

Civic, Recreational and Commercial Use: Water demand was based on the type of land use (actual use category, e.g. health clinic, school, church, firehall, store, hotel), information on specific sites obtained from internet sources (business websites, Island Health inspection reports) and communication with property owners (Island Health, 2025). Daily water use per activity, facility size, or parcel area were determined using published empirical values including water loading estimates for sewerage systems (Miles, 2009; Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2012; Ministry of Health, Health Protection Branch, 2014; Statistics Canada, 2023a; United States Department of Agriculture Forest Service, 2007). Cortes Fire Department has two facilities, one in Whaletown area with two wells and large 60 m^3 water storage tanks, and one in Manson’s Landing, with shallow well source. An unknown volume of water for storage tank filling and fire suppression is also reported to be taken from surface water sources (e.g., Gunflint Lake).

Industrial Use: No water use was assigned to the two industrial category parcels, associated with historical sand and gravel quarrying operations (non-operational).

Utilities: Electrical facilities were assigned no water use. Groundwater use for ferry operations was reported by the operator, based on their groundwater license application volume.

Manage Forests, Parks and Protected areas: No water demand was assigned to managed forest parcels, parks or protected areas. The exception was for Smelt Bay Provincial Park which has camping facilities with pit toilets and potable groundwater supply, for which water demand was estimated based on recreational water use estimates and campsite capacity (United States Department of Agriculture Forest Service, 2007).

6.4.7 Accuracy and sources of error

Surface water: Surface water demand was not directly included in the water demand estimate. Parcels assumed to be using surface water (with license POD’s), were excluded from the groundwater demand calculation.

Consumptive vs non-consumptive use: All groundwater use was assumed to be consumptive. Return flows from septic discharges or irrigation infiltration were not considered.

Actual households water use depends on the size of the home, facilities (e.g. number of bathrooms, bedrooms), area of garden and irrigated outdoor spaces, and occupancy patterns including seasonal guests, etc. Water use volume is also likely to vary depending on the productivity and reliability of the water source. Parcels with low producing wells or springs, for example, will likely be more conservative in their water demand. For these reasons, the methods used to estimate residential demand may overestimate actual water use on some lots. Similarly, agricultural water demand may be overestimated for parcels that are not irrigated.

Resorts and vacation rentals were not accounted for separately from other residential uses. Vacation rentals may increase overall occupancy (number of persons staying on each parcel) mostly concentrated in the summer months and shoulder season (late spring and early fall), and may bring more urban (i.e., less conservation conscious) water use patterns. There was no accurate way to estimate the number of homes or properties used for short-term rentals using existing datasets.

Non-domestic water users: In addition to 22 Island Health permitted water systems, the inventory of local water suppliers identified 17 potential non-domestic groundwater users on the island, including greenhouse/nursery facilities, institutions (fire halls), and commercial accommodations for which the regulatory including groundwater license status was undetermined. Water use for these systems was accounted for within the different water demand categories. Follow-up could be completed by the Ministry of Water, Land and Resource Stewardship to advise business and property owners regarding license requirements for groundwater users (Ministry of Water, Land and Resource Stewardship, 2024).

6.4.8 **Water demand results**

Monthly water demand for the three water use categories including agricultural, residential and seasonal use is shown in Figure 25. The largest water use by quantity is for residential use, followed by agricultural use. Commercial and institutional use includes public facilities, stores, camps, hotels, and other commercial operations for which seasonal peaking factors were applied to account for differences in seasonal population (e.g. tourists and increase in summer population on the island).

The proportion of groundwater demand compared to groundwater recharge for Cortes Island, individual water management areas and aquifers is evaluated in Section 6.5 below.

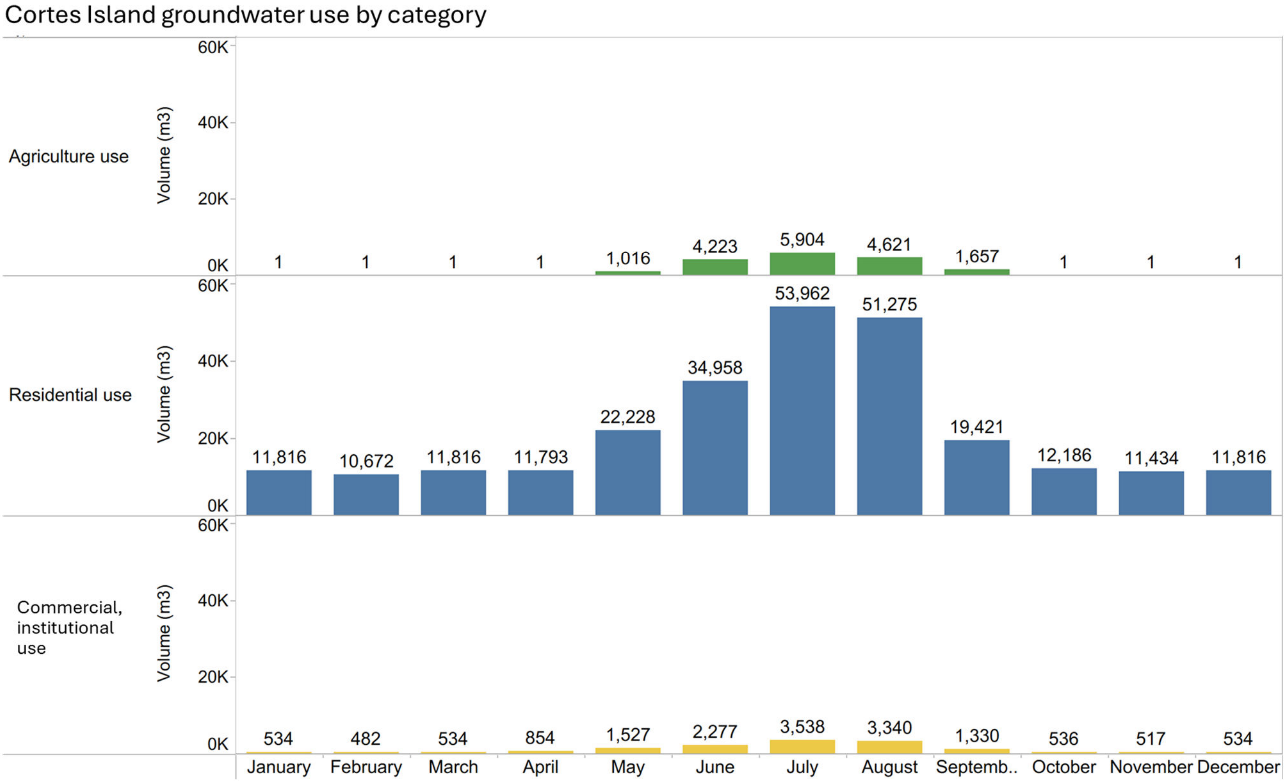


Figure 25. Cortes Island water use by water use category, including agricultural, residential and commercial-institutional seasonal use.

6.5 Water Balance Results

6.5.1 Climate

The Strathcona region receives abundant rainfall. For example, the long-term average precipitation at Campbell River Airport monitoring station, Environment Canada Station EC1021261) is 1420 mm per year (Figure 26), ranging from 936 mm to 1,965 mm/year from based on long-term datasets from 1965 to 2023 (Environment and Climate Change Canada, 2025). The average was calculated excluding data from the years 2008-2009 for which a significant proportion of data were missing).

Long-term trends in monthly total precipitation at Campbell River Station (EC101261) are shown in Figure 27. Although there is significant year-year variability, increasing precipitation trends are observed for the months of January, April and September, decreasing precipitation trend is observed for the months of February, March, July, August, November and December, while stable or no trends are observed for May-June. There are no active climate monitoring stations on Cortes Island.

6.5.2 Precipitation, Actual Evapotranspiration, Surplus and Groundwater Recharge

The results of the water balance model, including modelled precipitation, actual evapotranspiration, surplus and groundwater recharge based on climate normals (1980-2010) for Cortes Island are shown in Figure 28. Results for water management areas focused in the settled areas of Manson's Landing-Hague Lake, Squirrel Cove and Whaletown are provided in Figure 29. The following observations are made:

- Precipitation is greatest from October to March annually.
- Actual evapotranspiration fluctuates according to annual plant cycles and temperatures, and is higher in the months from April to September, showing the highest values in May.
- The surplus available for groundwater recharge is highest from November to January annually. No surplus is available from May to September.
- Groundwater recharge occurs during fall to winter months (mainly October to March), and minimal to no recharge is anticipated from April to September.
- The same seasonal patterns are observed for all the water management regions (Figure 29). Regions which extend into higher elevation watersheds have slightly higher quantities of precipitation due to orographic effects, and recharge quantity is greater in areas with unconsolidated aquifers.

6.5.3 **Groundwater Recharge Compared to Water Use**

Precipitation, recharge and groundwater use were estimated for all areas of the island and then broken down by water management area and aquifer. Figure 30 illustrates monthly groundwater recharge (A) and water use (B) for Cortes Island. Recharge was estimated as direct recharge over the spatial extent of the island, compared to water use in all regions. Groundwater recharge occurs mainly in the fall and winter (October-March) with very little recharge occurring in the summer months. Water use shows the opposite pattern with generally lower water use in the winter, and peak water use in summer (June to August). The water balance in all areas of the island thus has a seasonal deficit in the dry season during which water use must be supplied from storage in the aquifers.

Precipitation, direct recharge and water use were estimated for water management areas, and individual aquifers. Direct recharge refers to diffuse or focused recharge within the footprint of the management area or aquifer. For the Manson's Landing AQ841, in addition to direct recharge, a proportion of recharge was interpreted to originate from mountain block recharge (MBR) on upgradient slopes within the Hague Lake watershed, which are expected to contribute to aquifer supply through deeper regional flow systems and losses to groundwater from Hague Lake (Figure 40). Therefore, total recharge for AQ841 incorporated 15% of the upgradient drainage anticipated to originate as mountain block recharge and losses to the aquifer from the Hague Lake system. This estimate of indirect or mountain block recharge contribution is based on empirical estimates and could be re-evaluated if monitoring data was available to better quantify and understand the interrelationship between surface and groundwater sources in this area.

Monthly recharge by aquifer is shown in Figure 31 and monthly recharge by water management region is shown in Figure 32. Considering regional differences in recharge by aquifer, monthly and annual recharge quantity is greatest for AQ841 (sand and gravel). This aquifer is large in spatial extent with a moderately sloped surface, while the overburden sediments are permeable allowing greater recharge to occur. For the Squirrel Cove sand and gravel aquifer recharge potential is relatively high due to the permeable soils, overburden and aquifer materials, but the topography is more steeply sloped, and the spatial extent of sand and gravel deposits is smaller than in Manson's Landing (AQ841).

Bedrock aquifers have a lower groundwater recharge potential and are found in more steeply sloped areas, while recharge and groundwater movement are controlled by the properties of the bedrock fractures (density, aperture, connectivity, etc.). The estimate of recharge quantity to bedrock aquifers is strongly influenced by the areal extent of the mapped aquifer or water management area. Some smaller aquifer units which were mapped based on the area of groundwater development (locations of registered wells) may underestimate water recharge and availability.

Water use by aquifer is shown in Figure 33 and by water management region in Figure 34. Whaletown has the highest annual use and generally highest monthly use in comparison to other areas. Manson's Landing has the second highest water use, and highest July use, likely due to the presence of more agricultural lands and commercial operations which increases the seasonal demand in this area. In the remaining regions, water use is low, due to limited development and mostly managed forest land use in the central and northern areas of the island.

Calculating the ratio of water withdrawal to availability is a common method used to evaluate the degree of water stress for a water source or region (Alacamo et al., 2003). Renewable groundwater stress for an aquifer can be estimated by calculating the proportion of groundwater recharge that is used on an annual or other time-period. Various thresholds have been considered to indicate low, moderate or extreme levels of water stress, for example, the United Nations Renewable Stress Scale defines a low level of stress as from 0 to 10% of recharge being used, up to an extreme level of stress if 40% or more of available water is used (Richey et al., 2015). In BC, a presumptive limit of 10% diversion of replenishable aquifer storage has been proposed as a threshold for licensed groundwater allocation (Sivak et al., 2024).

Recognition of the inter-connection between groundwater and surface water environments has highlighted the need to consider the effects of groundwater pumping on environmental flow needs (EFNs) of nearby streams, and to exercise a precautionary approach to groundwater diversion that considers both inter-annual and seasonal limits, based on observed conditions in the aquifer (Allen and Gleeson, 2023; Forstner et al., 2018; Gleeson and Richter, 2018). Although caution should be applied to reliance on simplified water balance assessments without recognition of actual groundwater pumping impacts, where knowledge of an aquifer is limited, assessment of water stress (demand versus supply) is a relatable measure, that can be used to determine the relative state of the resource, to highlight where water use may be approaching sustainability thresholds and where further investigation or data collection may be warranted.

Considering a precautionary approach for this study, the aquifer and water region stress was estimated as the ratio of water use to recharge, ranked from low (5% or less) to extreme (greater than 20%), as shown in Table 17.

The results of the water balance assessment, including total annual precipitation, recharge and water use, groundwater recharge as a percentage of precipitation, water use as a percentage of recharge, and relative aquifer stress for Cortes Island aquifers (Table 18) and water management areas (Table 19) are summarized below, ranked in order from highest to lowest water use. AQ841 has the highest aquifer use, yet has a low aquifer stress, with approximately only 3% of annual recharge being utilized for groundwater supply. The aquifer stress is low for most aquifers on the island, with the exception of the smaller bedrock aquifers in the Whaletown area for which the aquifer stress is moderate to high. In comparison, at the scale of the water management regions, water stress is considered low for all areas, ranging from 4.8% (Cortes Bay West) to less than 1% in regions with low levels of development. The aquifer health assessment for key Cortes Island aquifer and regions is summarised in section 8 below.

Table 17: Aquifer stress categories

Aquifer Stress Category	
Water use / recharge	**Stress Level**
0 - 5%	**Low**
5 - 10%	**Moderate**
10 - 20%	**High**
>20	**Extreme**

Table 18: Cortes Island aquifers annual precipitation, recharge, and water use volumes and ratios, and aquifer stress category.

	Precip.	**Recharge**	**Usage**	**Recharge /Precip.**	**Use/ Recharge**	**Aquifer Stress**
Aquifer	**1000's m^3/y**	**1000's m^3/y**	**1000's m^3/y**	**%**	**%**	
841 (Sand and gravel)*	12,611	3,478	99	28%	3%	Low
844 (Bedrock)	3,434	340	24	10%	7%	Moderate
843 (Bedrock)	2,222	315	19	14%	6%	Moderate
842 (Bedrock)	3,473	347	15	10%	4%	Low
Squirrel (Sand and gravel)	4,285	956	11	22%	1%	Low
846 (Bedrock)	3,926	407	11	10%	3%	Low
Squirrel (Bedrock)	13,463	2,333	6	17%	0%	Low
845 (Bedrock)	365	36	6	10%	18%	High
Total	**43,778**	**8,211**	**191**			

Notes: *AQ841 precipitation and recharge includes contribution of 15% mountain block recharge from Hague Lake watershed. The aquifer stress level value is influenced by the area of mapped aquifer, which may be underestimated for small aquifers such as AQ845 that were mapped or delineated based on the locations of registered wells (i.e. area of development).

Table 19: Cortes Island management areas annual precipitation, recharge, and water use volumes and ratios, and aquifer stress category.

	Precip.	Recharge	Usage	Recharge /Precip.	Use/ Recharge	Region Stress
Water Management Region	**1000's m^3/y**	**1000's m^3/y**	**1000's m^3/y**	**%**	**%**	
Whaletown	14,803	1,674	79	11%	4.7%	Low
Manson's Landing	11,377	2,839	74	25%	2.6%	Low
Hague Lake	17,135	2,165	37	13%	1.7%	Low
Cortes Bay-Seaford	12,649	1,432	21	11%	1.5%	Low
Cortes Bay West	4,574	421	20	9%	4.8%	Low
Squirrel Cove	13,486	2,333	17	17%	0.7%	Low
Gorge Harbour South	6,026	610	13	10%	2.2%	Low
Gorge Harbour North	12,837	1,778	13	14%	0.7%	Low
Carrington Bay South	14,524	1,817	8	13%	0.4%	Low
Central Cortes	26,731	3,171	5	12%	0.2%	Low
Lewis Channel	10,630	1,168	4	11%	0.3%	Low
Carrington-Quartz Bay	6,964	829	4	12%	0.4%	Low
Northwest Cortes	14,450	1,977	-	14%	-	Low
Hathayim	17,650	1,979	-	11%	-	Low
Total	**183,833**	**24,194**	**296**			

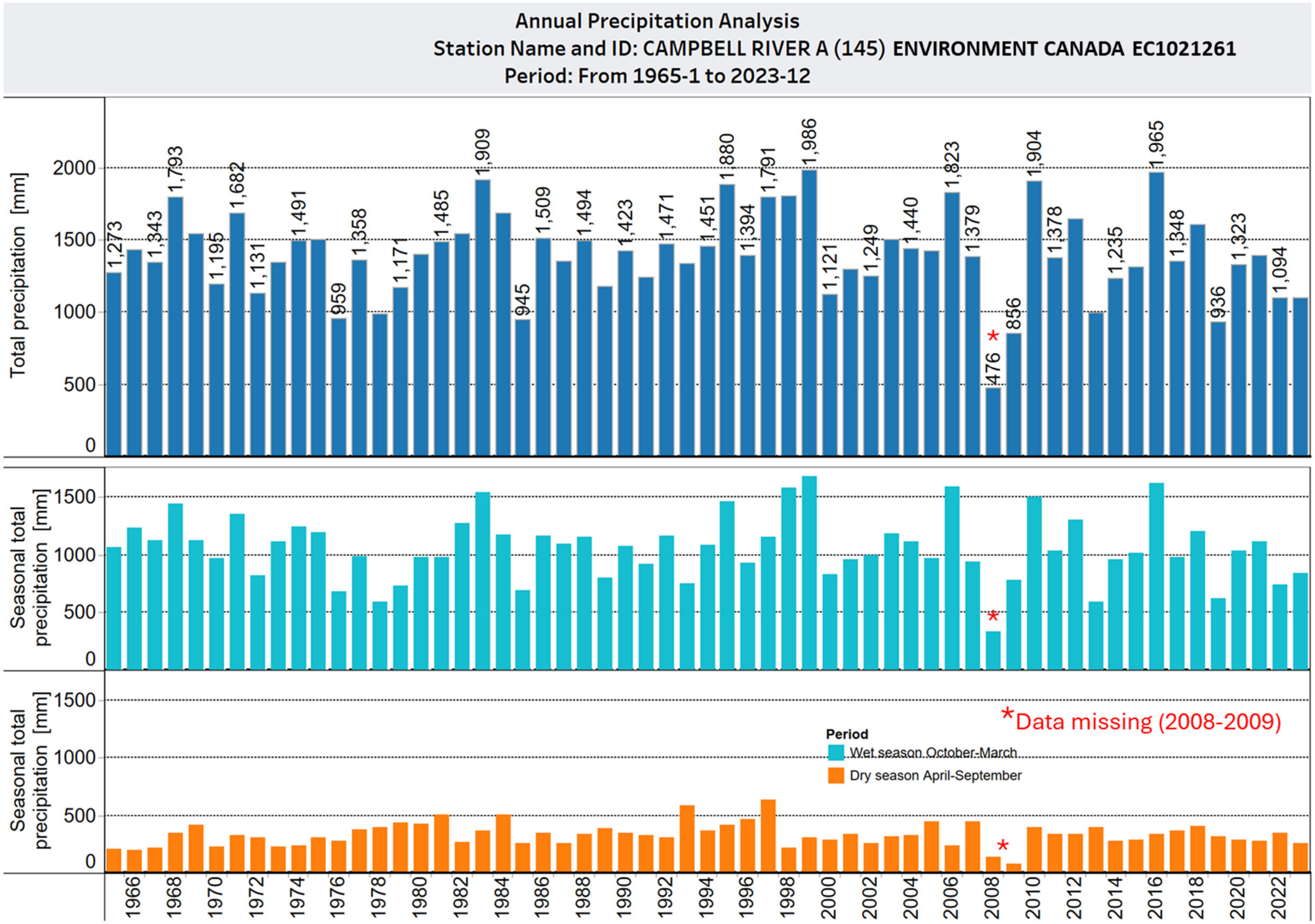


Figure 26. Annual, wet season and dry season total precipitation (1965-2023) at Campbell River Climate Station EC1021261, 15 km southwest of Cortes Island.

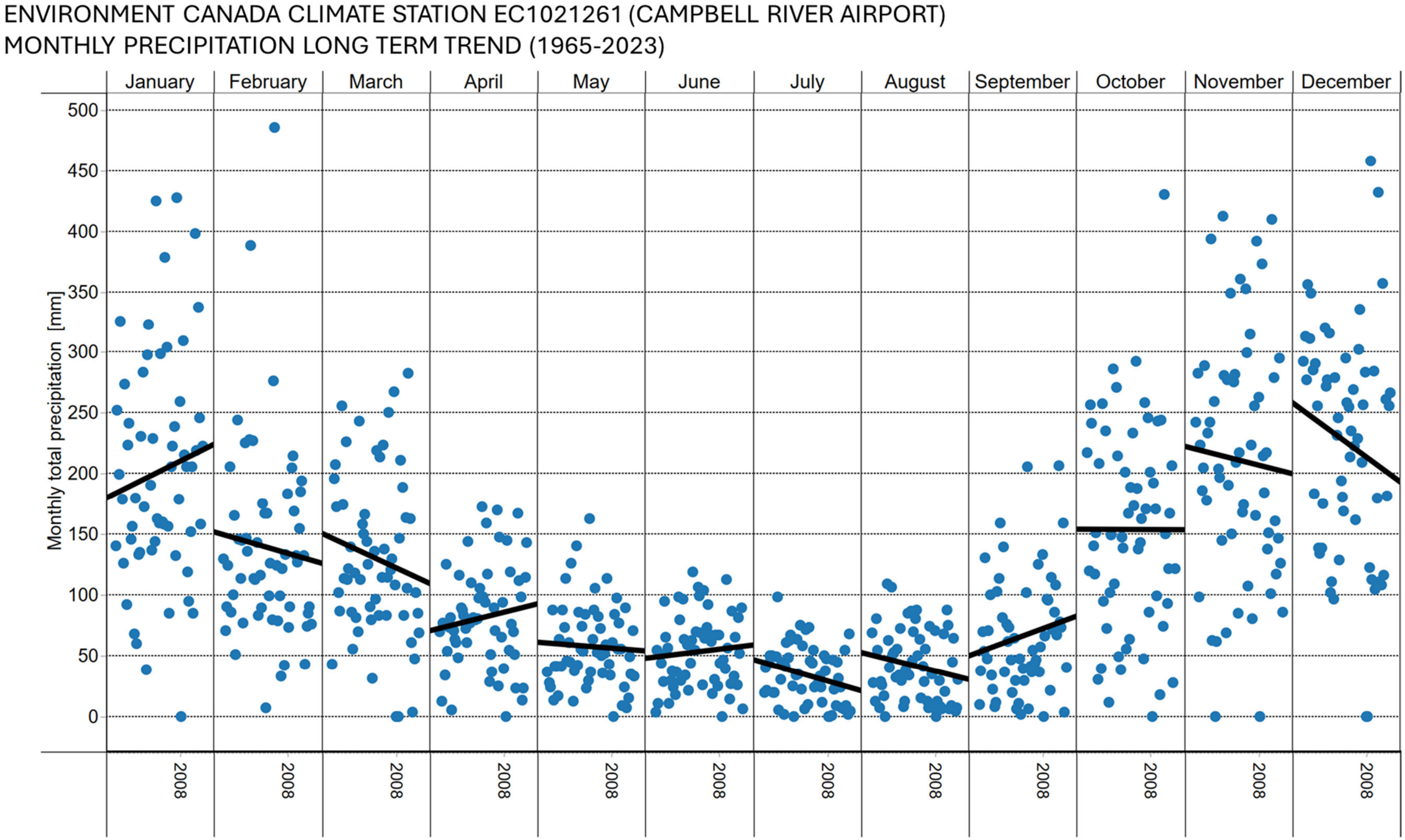


Figure 27. Monthly trends total precipitation (1966-2023), Campbell River StationEC1021261.

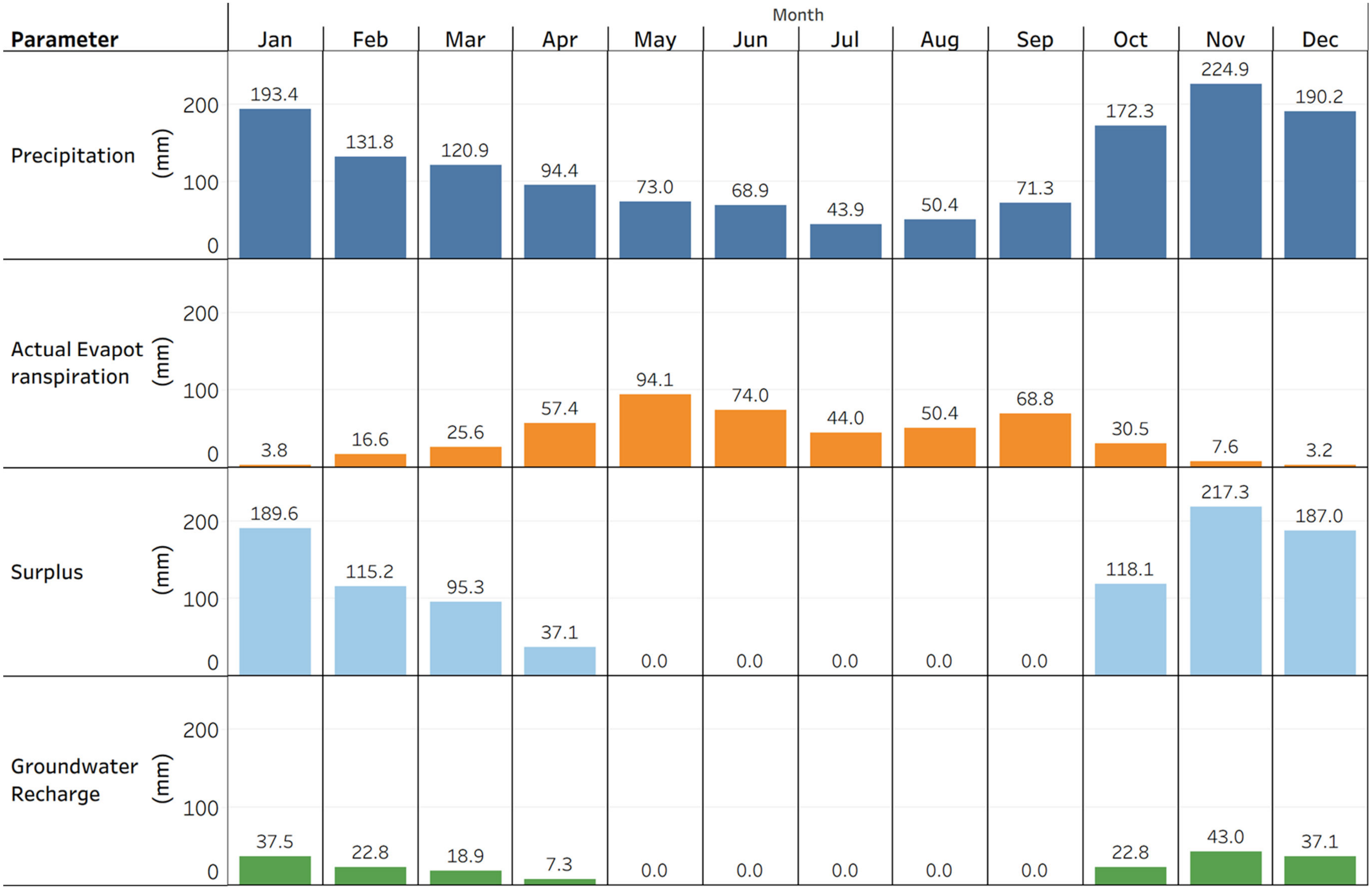


Figure 28. Cortes Island water balance model results: monthly precipitation, actual evapotranspiration, surplus and groundwater recharge (base case, climate normal 1980-2010).

Figure 29. Water balance model results: monthly precipitation, actual evapotranspiration, surplus and recharge for Manson's Landing, Hague Lake, Squirrel Cove, Whaletown Water Management Areas.

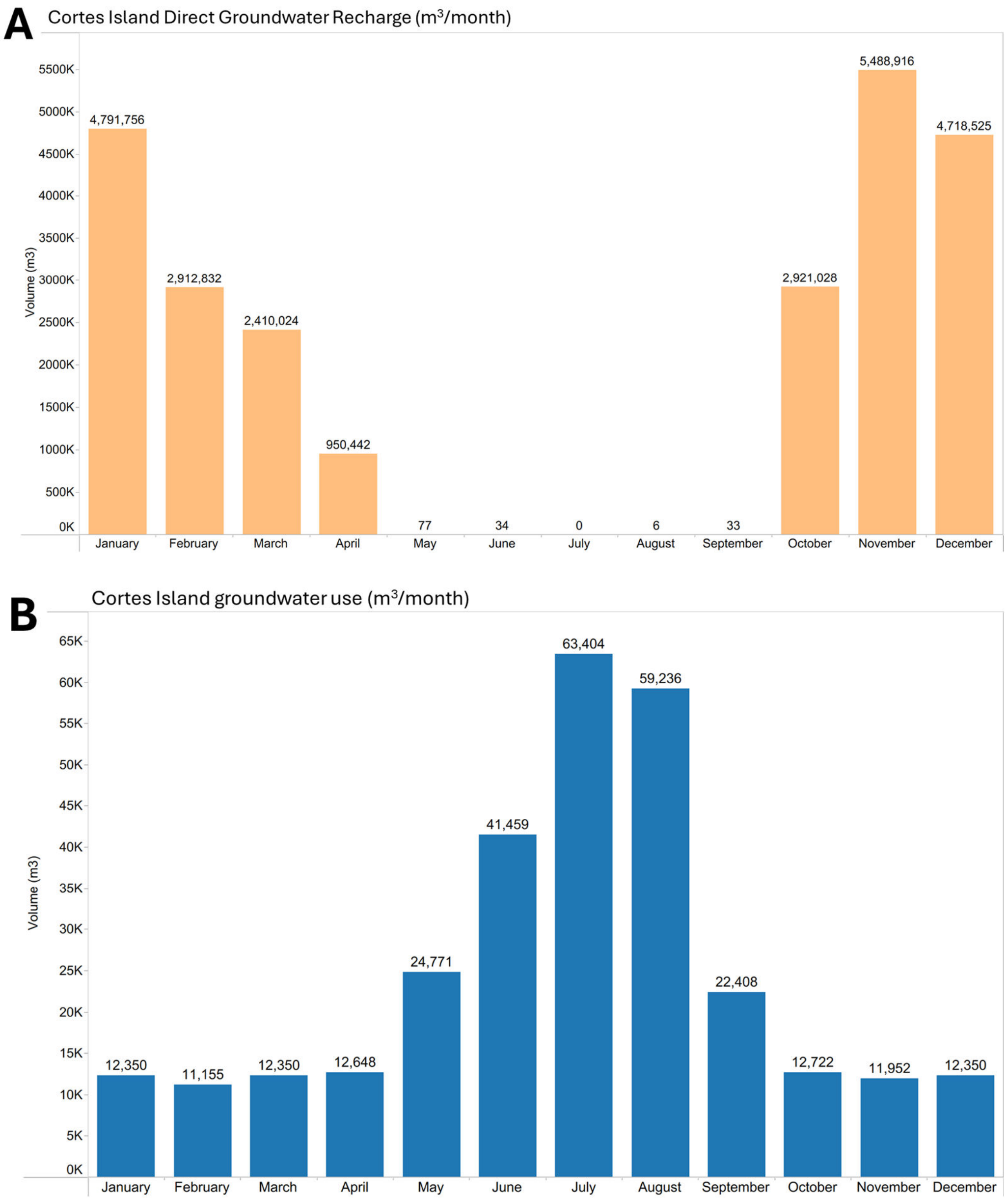


Figure 30. Cortes Island Direct Groundwater Recharge (A) and Water Use (B) and by Month.

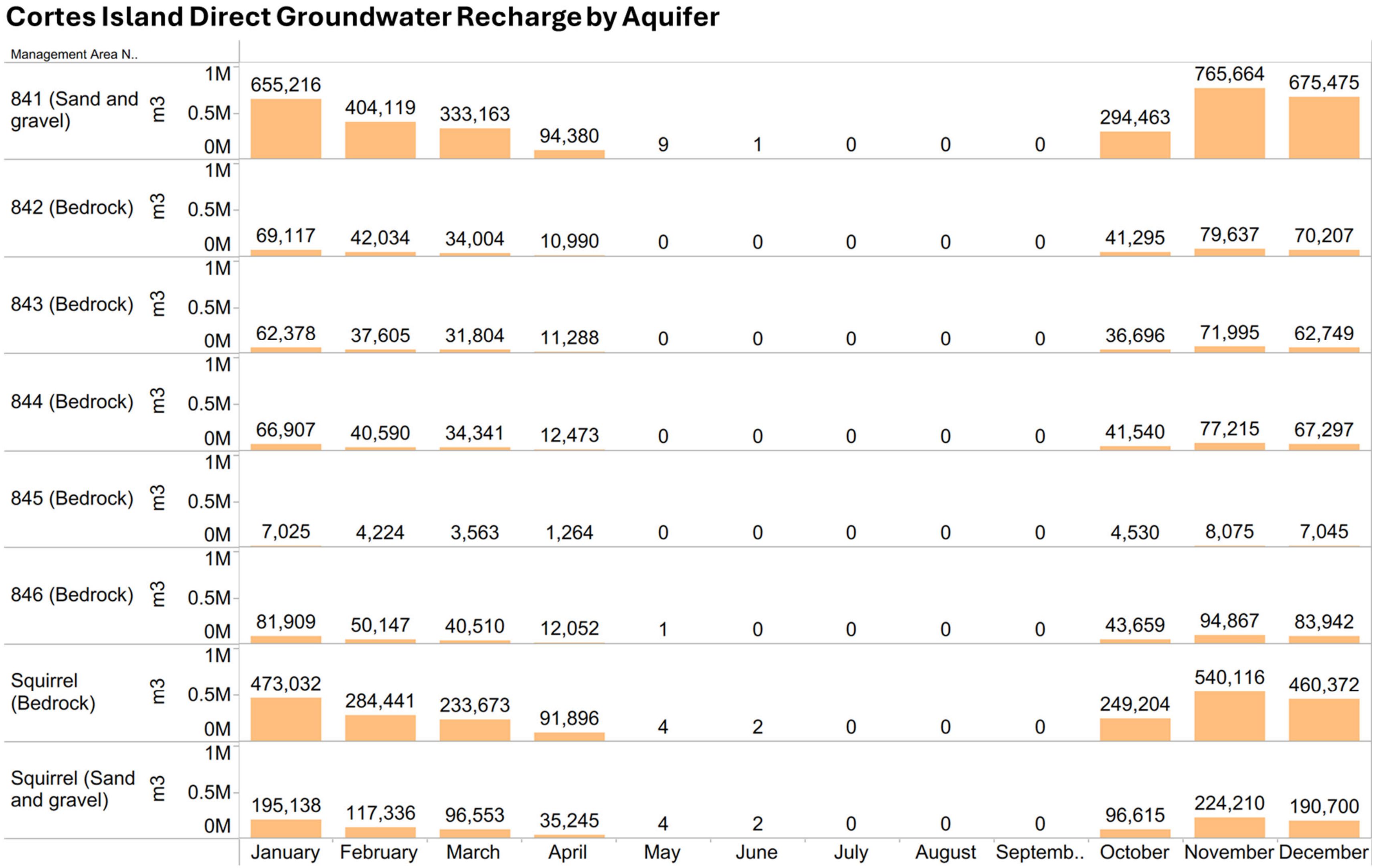


Figure 31. Cortes Island Groundwater Recharge by Aquifer.

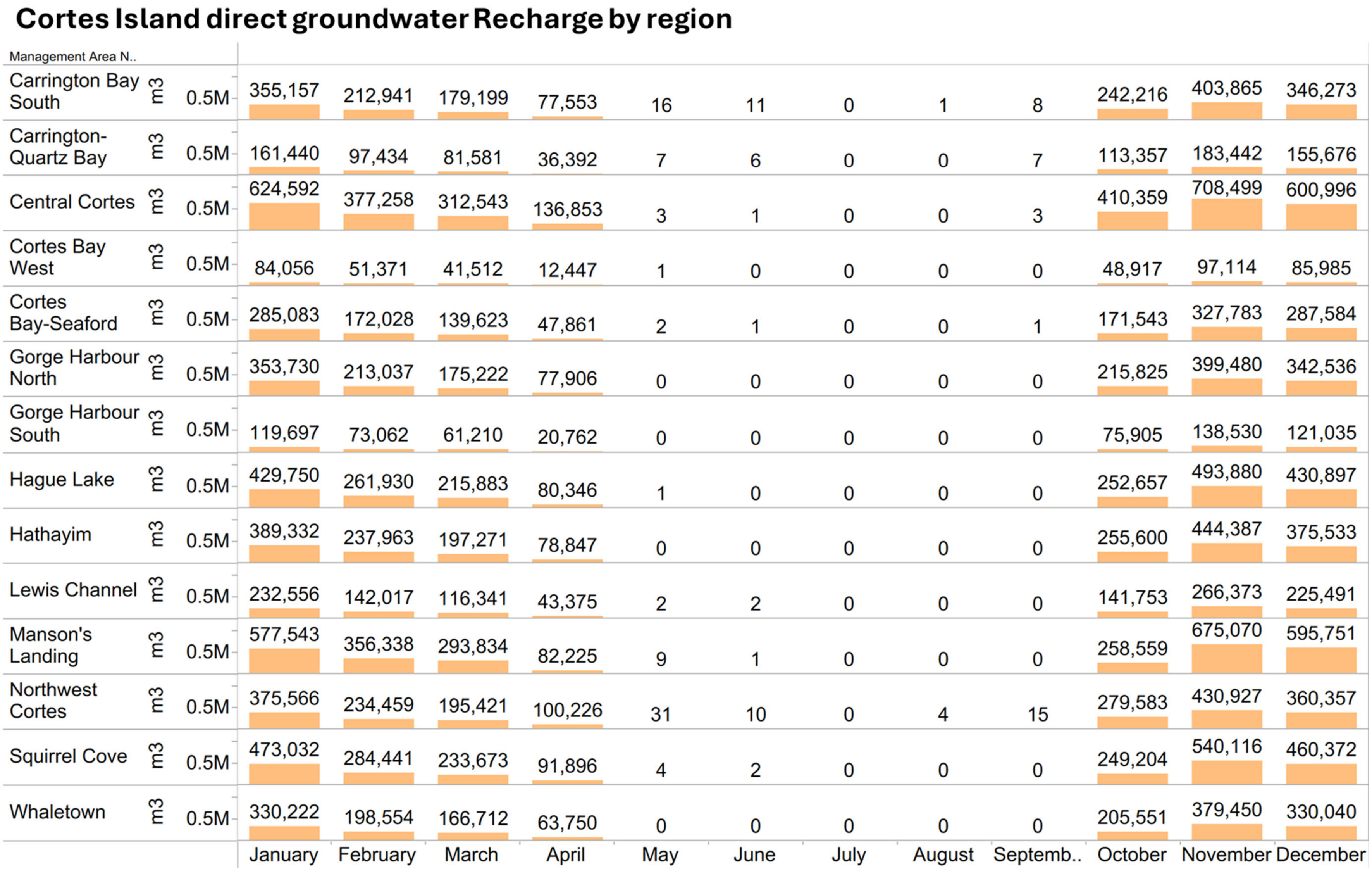


Figure 32. Cortes Island Direct Groundwater Recharge by Region.

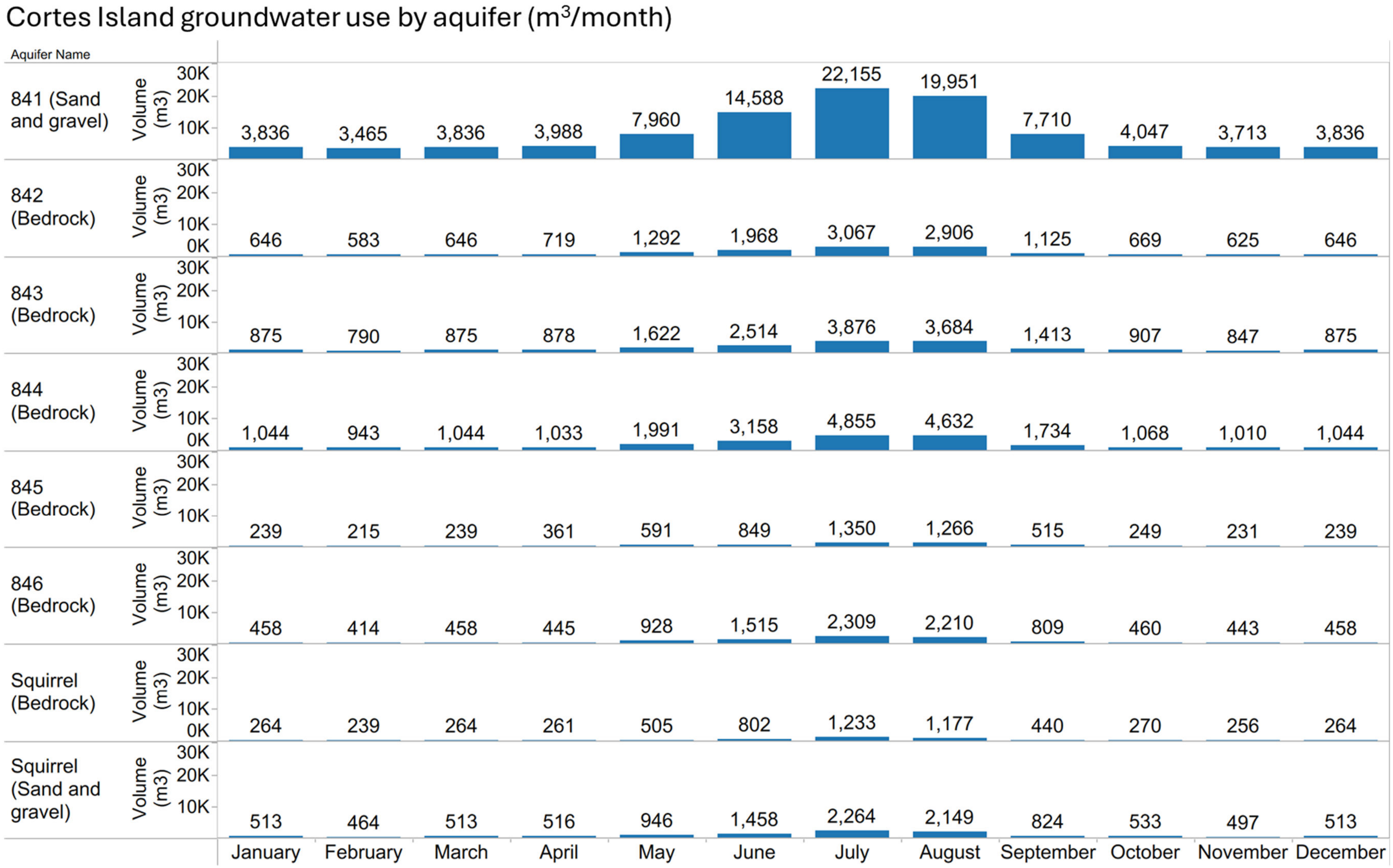


Figure 33. Cortes Island Groundwater Use by Aquifer.

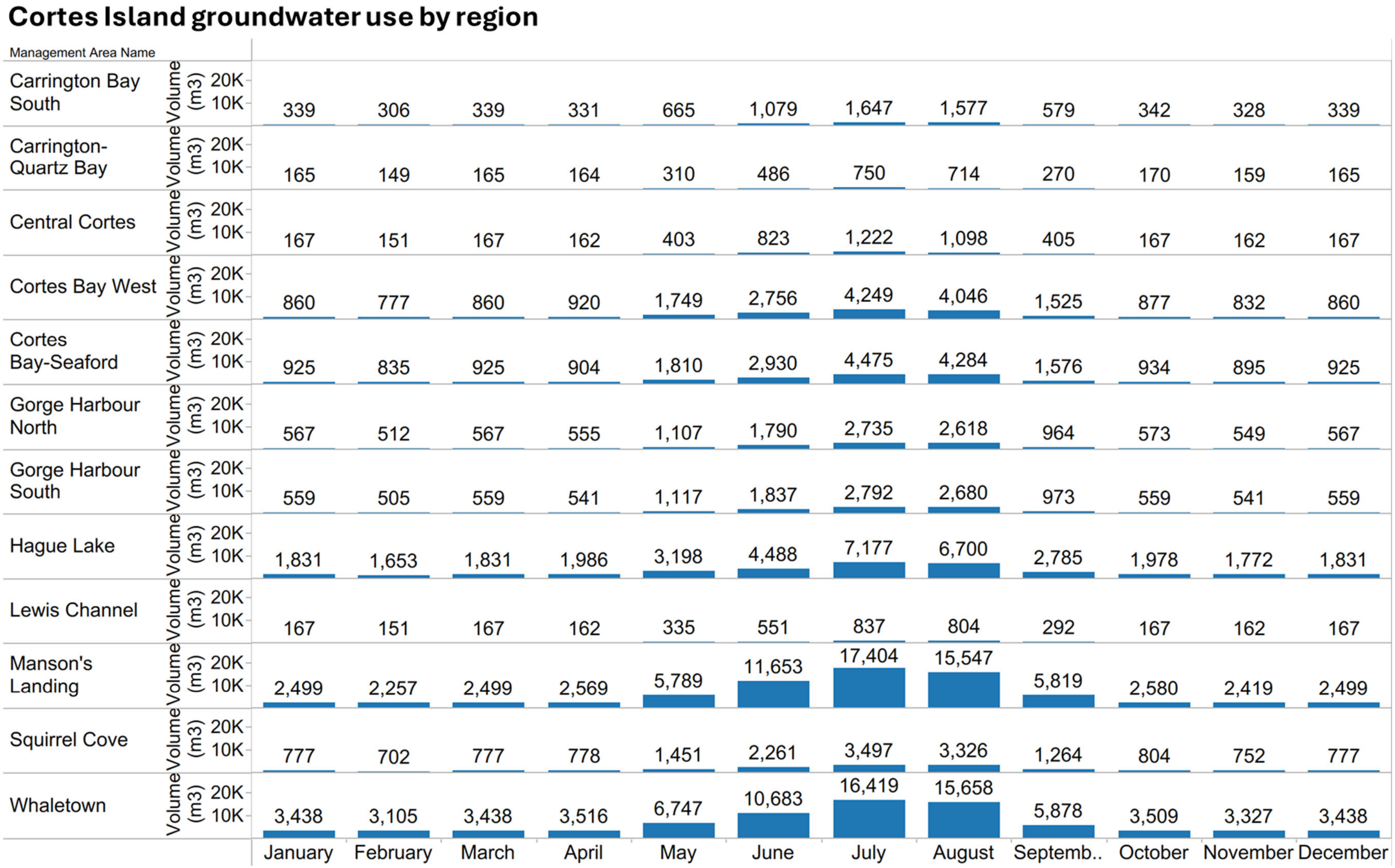


Figure 34. Cortes Island Groundwater Use by Region.

7 IMPACT OF CLIMATE CHANGE ON FRESHWATER RESOURCES

Climate change is one of the most challenging pressures facing humanity today. A key change associated with climate change is an increase in near-surface air and ocean temperatures which has profound impacts on the global water cycle affecting both the quality and quantity of freshwater systems (Bates et al., 2008).

Modelling of future climate for south coastal BC suggest that daytime high and nighttime low temperatures will rise. While temperatures are expected to increase year-round, the greatest increases will occur in the summer months. Monthly high and low temperatures show that the “new normal” for the region may be very unlike the past. Rising temperatures will lead to hotter summer days and nights and milder winters with the near loss of frost days and snowpack in all but the highest elevations. There may be a modest increase in annual precipitation by the 2050s, though the increase in precipitation will be distributed unevenly over the seasons. The largest increase is likely to occur in the fall season, while rain will decrease significantly in summer months. This region can expect stronger and more frequent extreme rainfall events, longer summer dry spells, and an extension of the dry season into September and October. In this context, some ways that climate change could affect freshwater resources on Cortes Island and in the Strathcona Region are summarized below.

Wetter Winters: Climate change is affecting how much and when rain and snowfall occurs, and how long winters last. In coastal BC, winter precipitation is expected to increase, mainly occurring as rain due to higher temperatures (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). Reduced snowpack accumulated at the end of the winter season will limit water storage, reducing the delayed release critical to groundwater recharge and needed for baseflow in river systems (Gullacher et al., 2023). Increased rainfall may lead to higher aquifer recharge, but this will be received over a shorter period, affecting the seasonal patterns of groundwater level response (Green et al., 2011). For example, groundwater levels may begin to decline sooner in spring, affecting water availability later in the summer.

Higher Intensity Rainfall Events: When the atmospheric temperature is warmer, it can evaporate and hold more moisture. Consequently, an increase in high-volume, high-intensity precipitation events is expected, especially during winter months (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). Sporadic, high intensity rainfall – rather than low-volume, temporally distributed rainfall – tends to produce a large amount of surface runoff (soil erosion, flooding) but reduces groundwater recharge as there is a limit to the amount of water that can infiltrate into most soils at any given time (Green et al., 2011).

Increased Evapotranspiration: Higher evaporation (from all surfaces, soils, and water bodies) and higher transpiration from vegetation is expected, due to an increase in temperature, leaving less water to infiltrate into the soil and causing a reduction in groundwater recharge (Bates et al., 2008).

Droughts: Longer, drier summers will increase the risk of drought and reduce water availability during the dry season (Pacific Climate Impacts Consortium (PCIC), Capital

Regional District (CRD), 2024). On Cortes Island, as in other communities, seasonal peak water use also coincides with the period of lowest seasonal water availability, which will necessitate careful management of water supplies.

Increased Water Demand: Higher temperatures and longer dry seasons are likely to increase water demand. A significant portion of residential water demand during spring and summer periods is associated with outdoor use (for garden watering and landscape maintenance), therefore the water needs for household use are likely to increase during longer and drier summers. The period and amount of water needed for agricultural irrigation is also likely to increase. For example, Gilchrist (2017), estimated that future agricultural water demand is likely to increase in the Vancouver Island region, potentially up to double current demand under higher carbon emission scenarios.

Degradation of Water Quality: Decreased groundwater recharge or changes in the timing of recharge can lead to a reduced groundwater baseflow to surface water and thus there will be less surface water flow and less dilution of natural minerals (iron, manganese, arsenic) (Green et al., 2011). Higher rainfall intensity may increase the impacts of pollutants from human sources such as septic systems. For example, rapidly increasing infiltration during rain events can lead to shallow drainage of septic discharge (containing potential pathogens and nutrients such as nitrogen and phosphorus) in groundwater emerging at downgradient surface water supply sources. These factors may result in increased concentrations of harmful substances in the water, negatively affecting aquatic environments, and undermining the health and sustainability of groundwater and groundwater-dependent ecosystems.

Seawater Intrusion: Island aquifers are particularly vulnerable to the effects of sea water intrusion (Werner et al., 2013). Climate change will result in long-term sea level rise; while, during periods of storm surge sea levels may further increase temporally, and lowland areas may be overtopped by waves (Thissen et al., 2024). High densities of water supply wells, intensive groundwater use and over pumping during the dry season can increase stress on limited freshwater resources in coastal areas (Sivak and Wei, 2021; Werner et al., 2013). Seawater intrusion processes, impacts and management are discussed further in Section 8.

Increased Fire Risk: Hotter temperatures contribute to higher rates of evaporation, lower atmospheric humidity and drying of vegetation and soil, increasing fire risk in a warming climate (Pacific Climate Impacts Consortium (PCIC), Capital Regional District (CRD), 2024). Rural communities in forested areas face an increasing hazard of forest fire related impacts. Fires can directly affect water resources by damaging water related infrastructure (distribution and treatment plants, pump systems, piping). Loss of vegetation, and alteration of soil structure reduces the ability of the soil to absorb water in fire damaged areas, increasing runoff and risk of landslides and flooding (Moazeni and Cerda, 2024). Changes in groundwater and surface water quality can also occur over a longer-term following a fire, including increasing water turbidity and the concentration of nutrients and other minerals (i.e. arsenic, nitrate, potassium, phosphorus, and dissolved organic carbon) (Emelko et al., 2011; Moazeni and Cerda, 2024).

7.1 Model-Predicted Climate Conditions for the Next Decades

The impact of climate change to the water resources of the study area was analyzed using data from the ClimateBC/ClimateNorthAmerica data project (Wang et al., 2016) which provides statistically downscaled climate projection data across BC, based on a selection of models from the IPCC's Coupled Model Intercomparison Project (CMIP6). The CMIP6 Global Climate Models (GCMs) aim to estimate the patterns of future climate change under different scenarios of climate "forcing." These scenarios are called "shared socio-economic pathways" (SSPs) meant to represent various possible socio-economic pathways that society could take to respond to climate change in the coming years (Riahi et al., 2017).

In the present analysis, four SSP scenarios have been considered, SSP 1.26, 2.45, and 5.85 spanning the range from more optimistic (gradual but pervasive shift to sustainable path, low challenge to climate mitigation and adaptation) to pessimistic (continued development of fossil fuels, high challenges to mitigation, and reliance on technological adaptation) (Government of Canada, 2025). Future climate change under each of these scenarios was predicted for three time-periods – 2025, 2055, and 2085.

Using the projected climate change for the four SSPs in the three future periods, monthly groundwater recharge was calculated for each scenario and compared the results to the historical "normal" values (1981-2010), as summarized in Figure 35, Figure 36 and Figure 37. The model results suggest the following:

- Groundwater recharge may increase in some fall and winter months, including in October, December and January. Although there is also a relative increase of recharge in September, the overall quantity of recharge in this month is still anticipated to be low, relative to other periods of the year.
- Recharge is likely to decline earlier in the spring. April recharge will decline, and the period of little to no recharge is anticipated to extend from April through to September (6 months), suggesting that the dry season is likely to lengthen significantly compared to present. This is anticipated to cause groundwater levels to decline earlier in the spring, increased drought conditions to be observed in the mid-late summer, and aquifer replenishment to begin later in the fall.
- The results are not significantly different for the future periods. This highlights some limitations of the model in being able to predict future climate conditions. The models also do not take into account extreme events and their potential impacts.

The results are consistent with other regional climate change studies. Increasing temperatures, particularly during the summer months, combined with higher solar radiation and lower summer precipitation will mean less groundwater recharge will occur in summer, while dry conditions will start earlier in the spring, and last later into the fall. The current hydrological regime, however, already operates within a pattern of excess water during the winter and deficit during the summer. The impact of climate change on this system will reduce the available window or annual time-period for groundwater recharge, and increase water stress during the dry season, when water use is the highest. A longer dry season will also increase soil and plant moisture stress, increasing fire risk in vegetated areas.

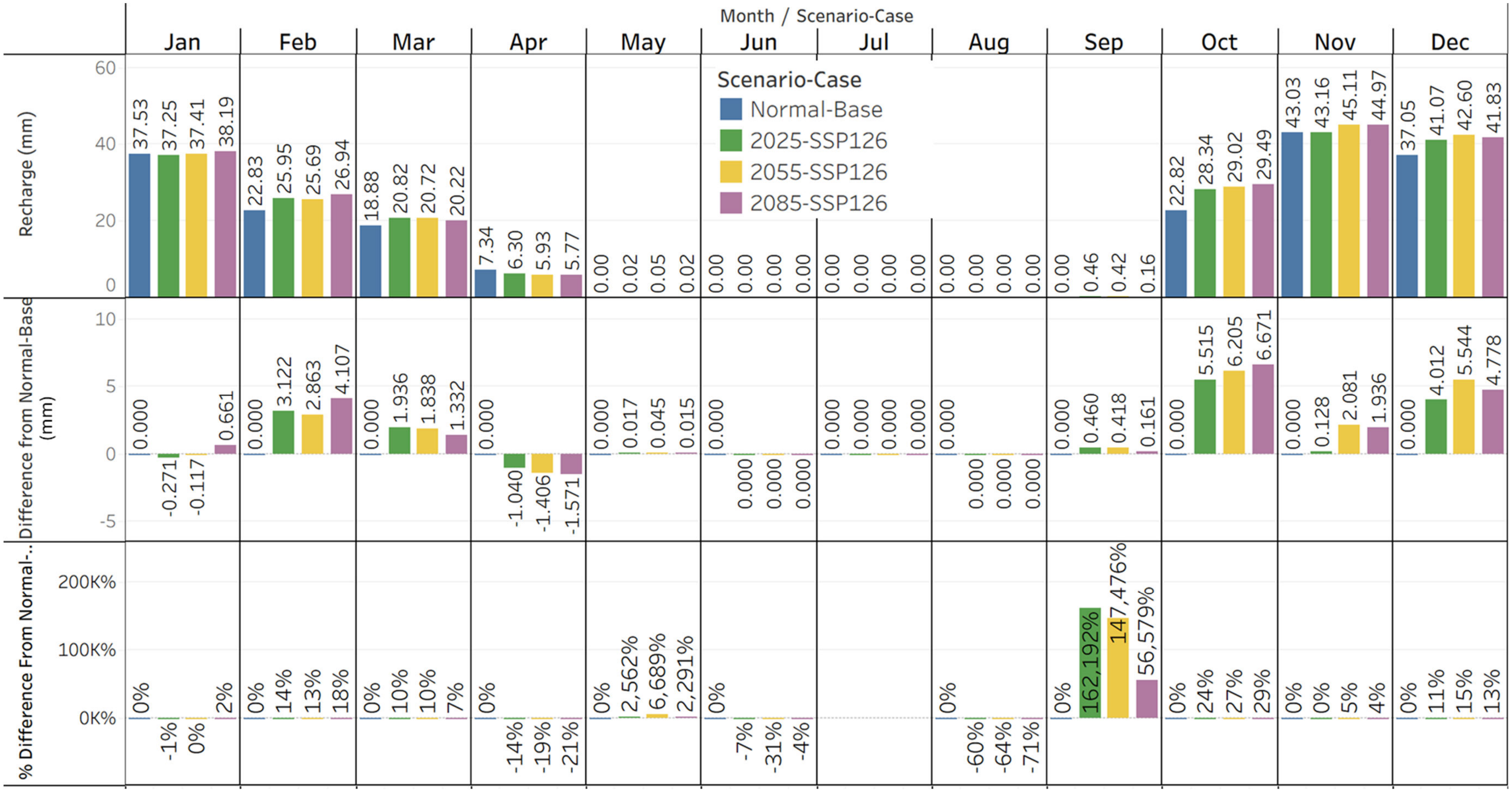


Figure 35. Cortes Island modelled monthly recharge (mm), difference (mm) and percent change relative to 1981-2010 climate normals, for 2025, 2055 and 2085 based on SSP 1.26 (low emission scenario).

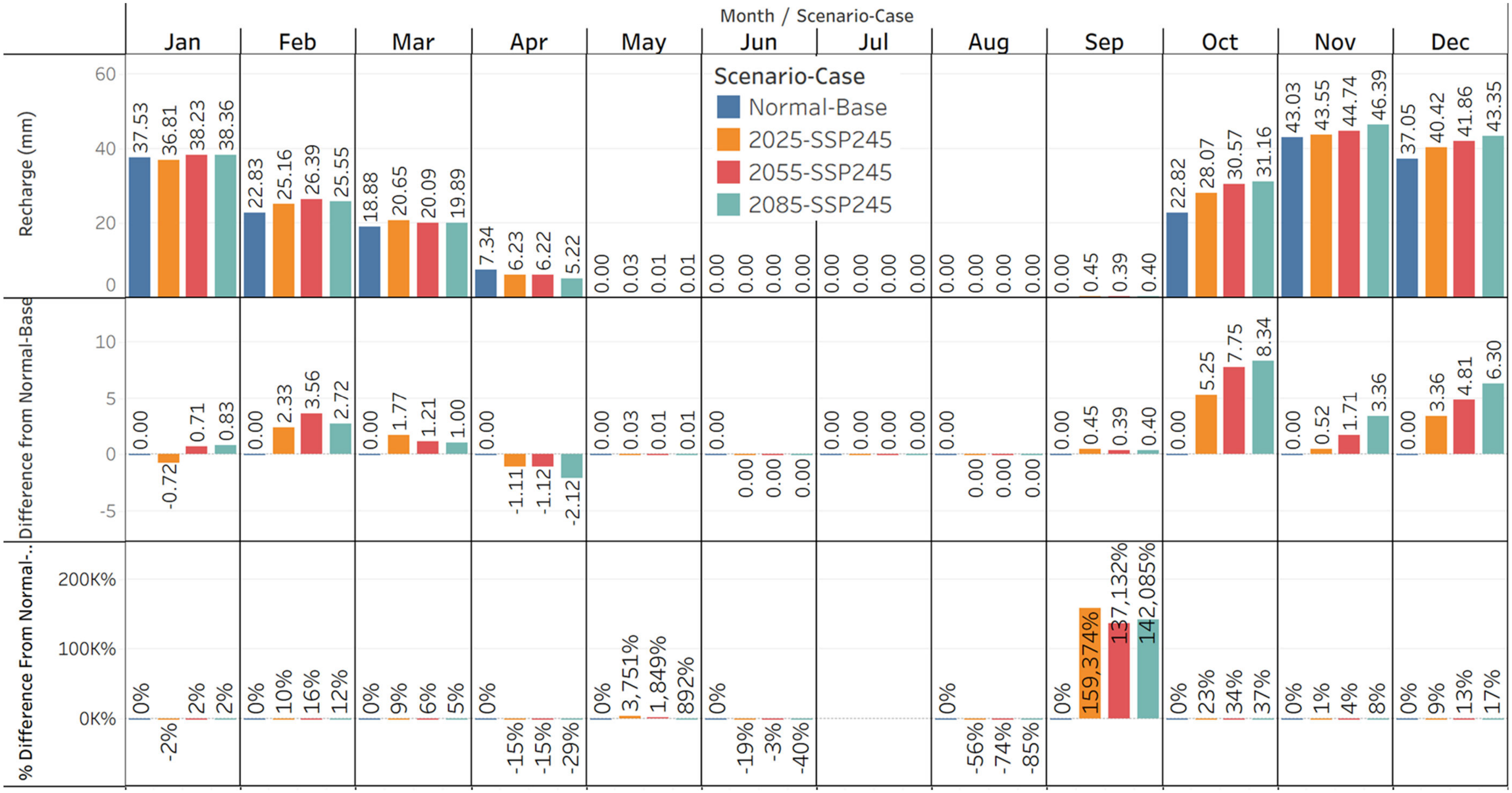


Figure 36. Cortes Island modelled monthly recharge (mm), difference (mm) and percent change relative to 1981-2010 climate normals, for 2025, 2055 and 2085 based on SSP 2.45 (moderate emission scenario).

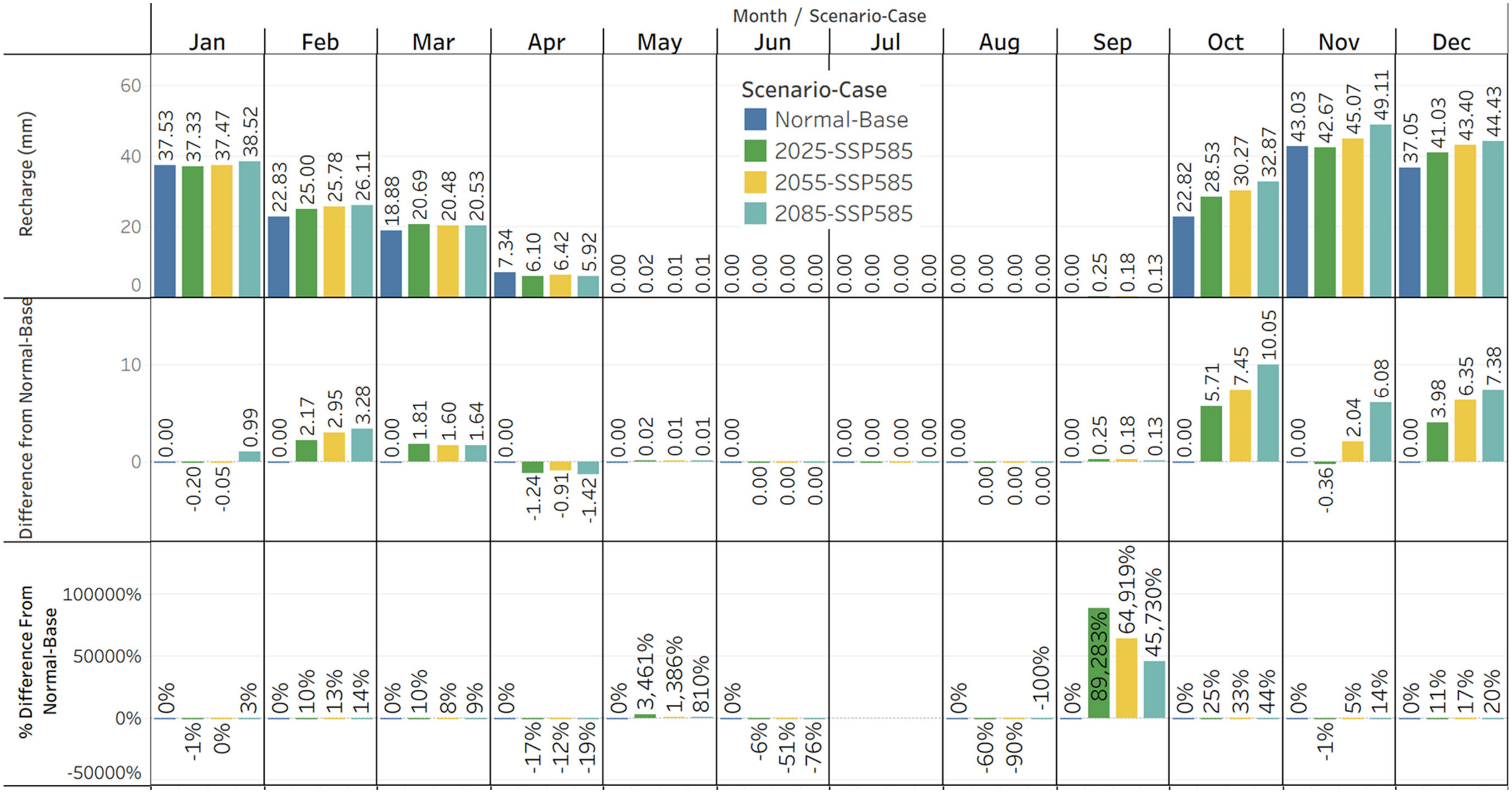


Figure 37. Cortes Island modelled monthly recharge (mm), difference (mm) and percent change relative to 1981-2010 climate normals, for 2025, 2055 and 2085 based on SSP 5.85 (higher emission scenario).

8 AQUIFER HEALTH ASSESSMENT AND REGIONAL SUMMARY

8.1 Mansons Landing and Hague Lake Water Management Areas and AQ841

The water balance results for the Manson’s Landing and Hague Lake Water Management areas were combined due to the interpreted interrelationship between the flow systems in each area, which span two watersheds, and incorporates the mapped extent of the Manson’s Landing Unconsolidated Aquifer AQ841.

8.1.1 Aquifer Characteristics

AQ841 is made up of glaciofluvial deposits, associated with the Quadra Sand lithostratigraphic unit, described in well records as well sorted sand, with minor silt and gravel. Wells in AQ841 range in depth from 16 to 110 m (12 to 230 ft), while the depth to groundwater ranges from 4 to 70 metres below ground surface (mbgs) with an average of 40 m (132 ft) bgs based on water level measurements recorded at the time of well construction. Figure 38 shows a map of the aquifer, wells and water sources in this area.

Much of the area immediately surrounding Hague and Gunflint Lakes includes bedrock exposures, with shallow overburden. Although a bedrock aquifer could be mapped around the lakes, few wells are currently constructed in this area to validate subsurface conditions. Many of the properties surrounding Hague Lake use water from the lake. Exposures of thicker unconsolidated deposits occur mainly along the southern margin of Hague Lake, the mapped northern extent of AQ841, while bedrock outcrops border the lake on its north and west sides.

The productivity of AQ841 is considered moderate. Current well yield and density statistics were calculated based on wells currently registered in the GWELLS database (2025). Estimated well yields range from 8 to 227 L/minute (2 to 60 USgpm). The aquifer has 95 correlated wells, corresponding to a moderate density of 10 wells per km^2.

8.1.2 Water Availability and Use

Water use is primarily for residential purposes, with commercial and institutional use in the village area in and around Beasley Road, and agricultural use in the central and southern part of the aquifer toward Sutil Point. Groundwater use from AQ841 is estimated as 99,000 m^3 per year, and the level of aquifer stress is considered low. This aquifer is the most significant water source on the island and can accommodate additional development. However monitoring is critical to understand aquifer conditions and evaluate change over time. If areas of higher development density are to be considered, careful planning and establishment of community water supply wells, and shared sewerage systems with adequate setback from well capture zones is recommended, rather than subdividing small parcels with one well and septic system each.

8.1.3 Vulnerability to Contamination

AQ841 is lithologically confined and overlain by layers of fine-grained materials including silt, clay and glacial till or hardpan (densely compacted, silt, sand and gravel) with a median thickness of 63 m. This confining layer protects the underlying aquifer by slowing the infiltration of potential contaminants introduced at the land surface, therefore the aquifer vulnerability is considered low (Hodge, William S., 2007b). Sources of contamination from land use are primarily sewage discharges to ground via septic systems.

8.1.4 **Likelihood of Hydraulic Connection**

In the Manson's Landing-Hague Lake area, the surface topography suggests that there is overland flow from the main village (Beasley Road) toward the lake. However, Hague Lake water level appears to be perched above regional groundwater levels and likely contributes to recharge of AQ841 (Figure 39). Additional monitoring is needed to examine the relationship between the lake and groundwater system and regional flow direction within AQ841.

Cortes Island has numerous lakes and river systems oriented along lowland valleys. Shallower groundwater levels highlight these areas as locations of groundwater discharge. One such example is the northeast trending Hague Lake, Gunflint Lake, and Slack Creek corridor which is oriented along and intersects with several linear geostructural features, indicative of the likely presence of major faults or fracture systems. This suggests there is a strong probability of connectivity between the groundwater and surface water systems. In comparison, linear features and faults in upland areas are inferred to be locations of probable focused groundwater recharge (Figure 40 and Figure 41).

Springs mapped in the eastern Manson's Landing area may be linked to a perched groundwater flow system. AQ841 is confined by a thick unsaturated layer of silt, silty clay, and till (Figure 42). In places where the confining layer has a very low permeability (e.g., deposits of dense/compacted fine sand, silt and clay aka till), shallow recharge may preferentially flow laterally and towards the coast. Spring flows were observed along the beach above and below the tideline on the eastern coast of Manson's landing. Landowners in this area report shallow groundwater wells and springs that appear to intersect a flow system that is distinct from the water levels intercepted by deeper wells. These shallow or perched flow systems may be vulnerable to land use changes including drainage for land development, and seasonal variability in precipitation.

8.1.5 **Seawater Intrusion Hazards**

Overall hazard of seawater intrusion in AQ841 is anticipated to be low. From Manson's Landing area and south down the Sutil Point Peninsula, the central area of the aquifer has a relatively deep freshwater lens, and the groundwater table is estimated to have a thickness approximately 10 to 15 meters above sea level (Figure 43). Seawater intrusion hazard in this aquifer may be higher near the shore and in areas where there are greater number of wells or higher volumes of pumping, such as on the southeast coast of the peninsula. Wells constructed in fractured bedrock along the west side and east sides of the Manson's Landing-Sutil Point Peninsula (e.g., AQ846) may be at higher risk of seawater intrusion if they are constructed deep below sea level or intersect saline fractures.

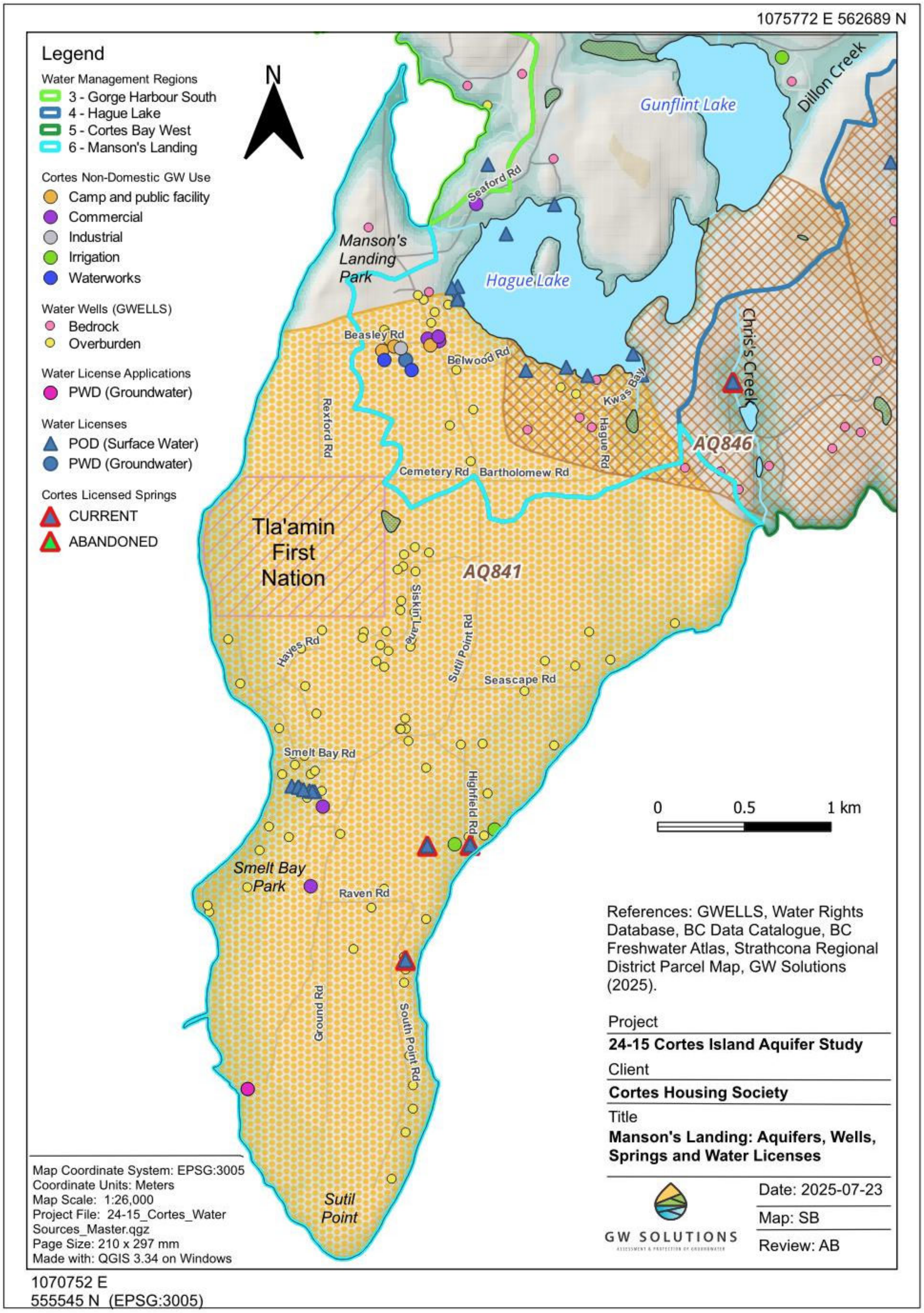


Figure 38. Manson's Landing aquifers and water sources.

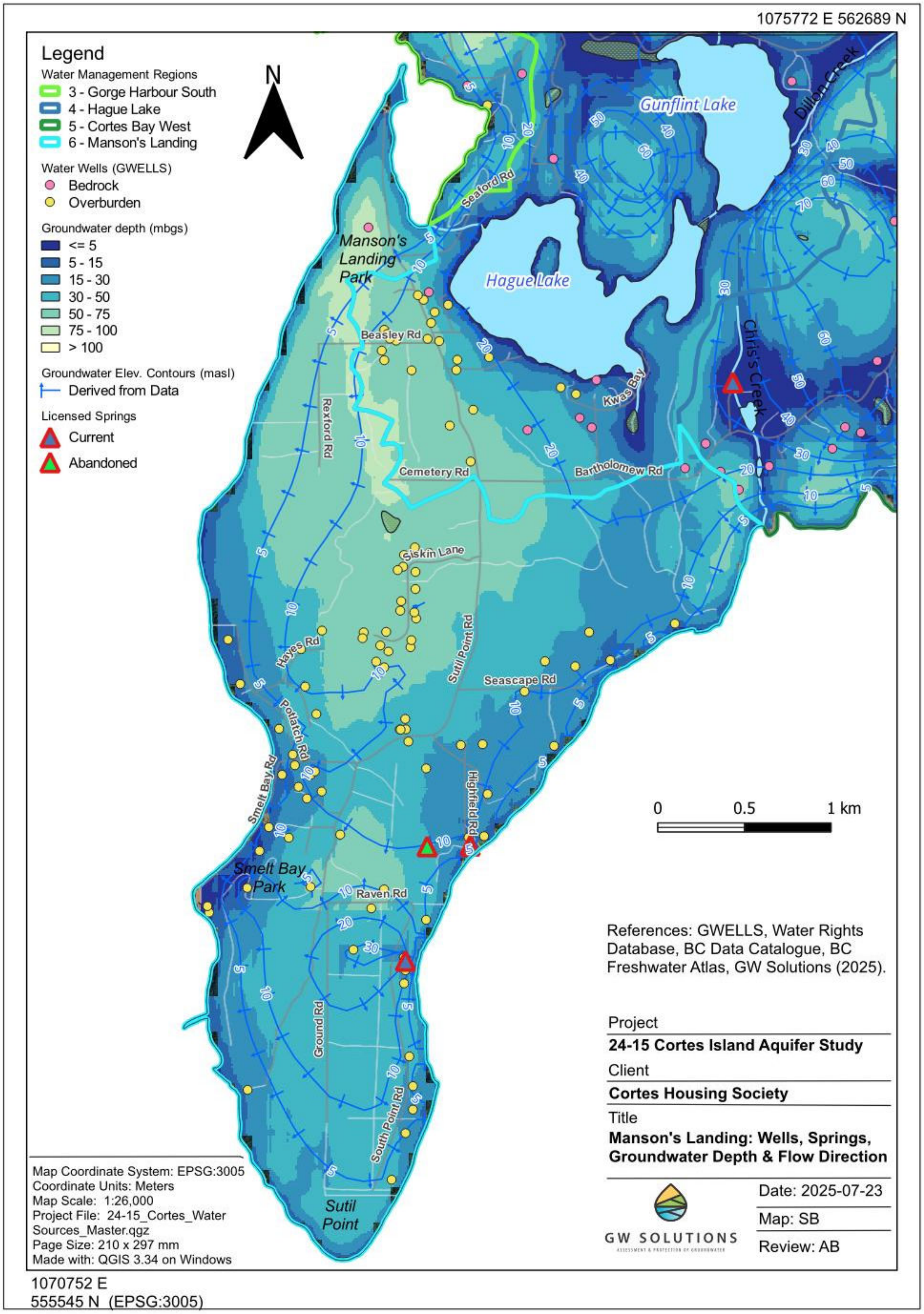


Figure 39. Manson's Landing groundwater depth and flow direction.

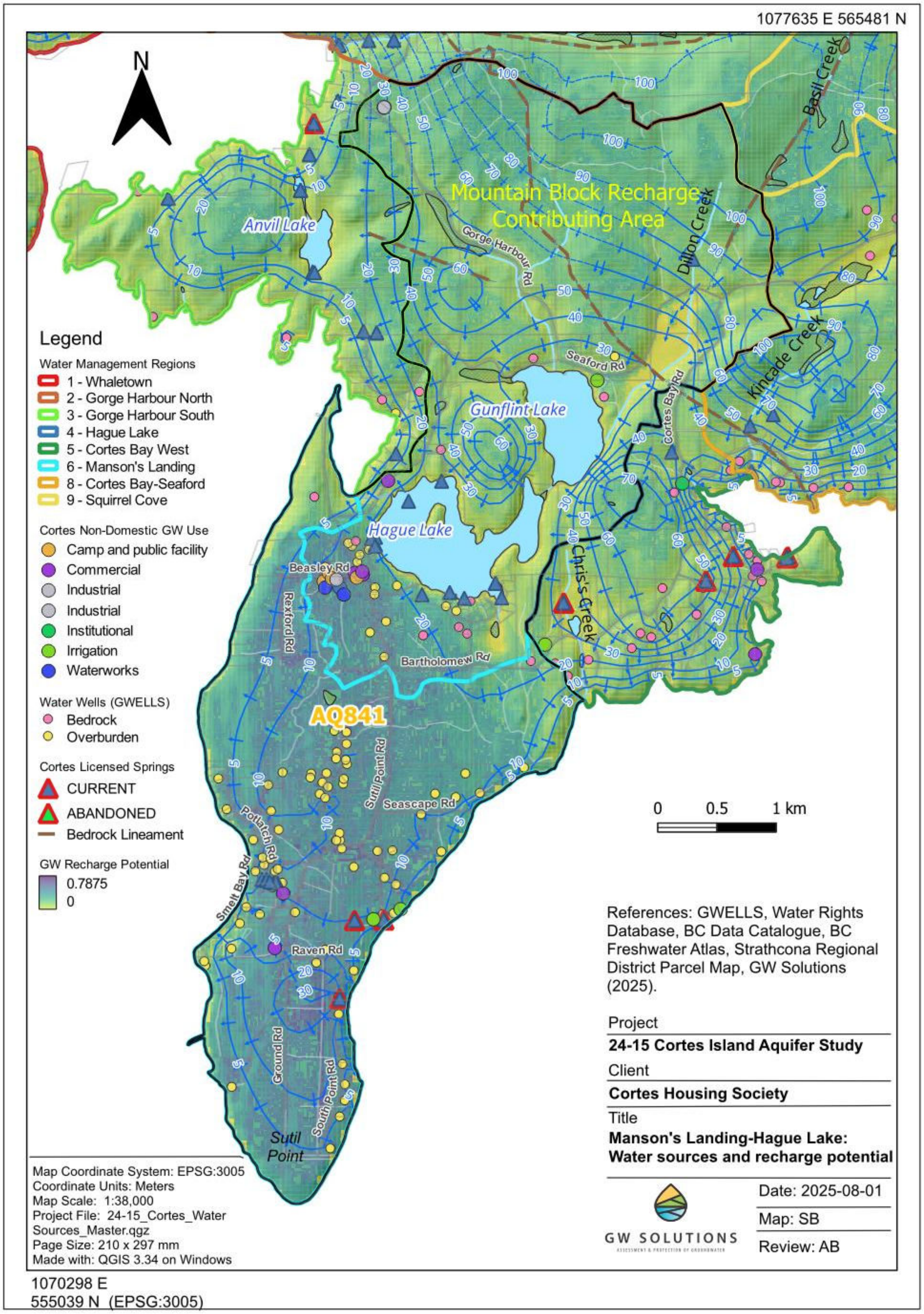


Figure 40. Manson's Landing AQ841 Hague Lake watershed mountain block recharge contributing area.

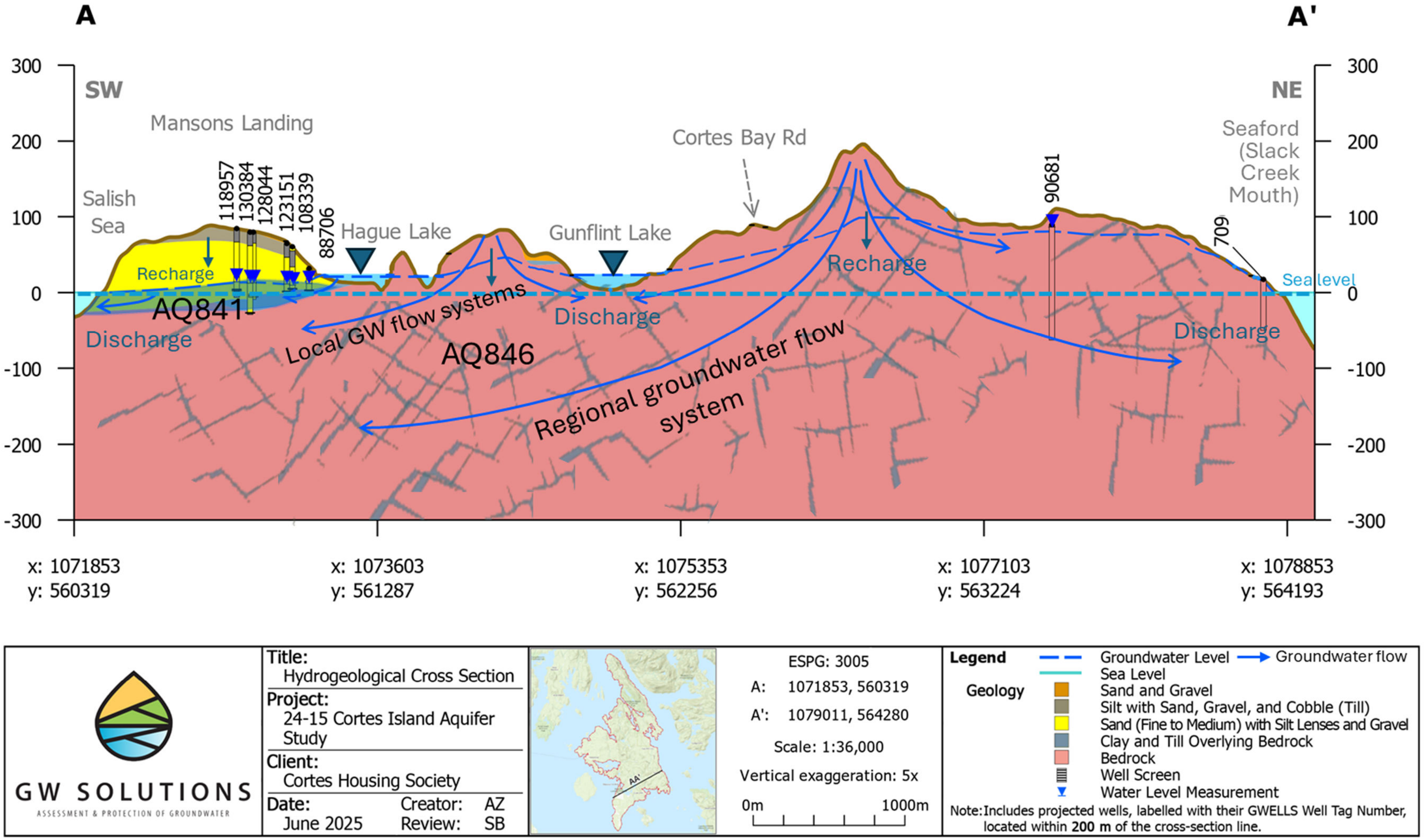


Figure 41. Cross-section A-A' Manson's Landing to Seaford.

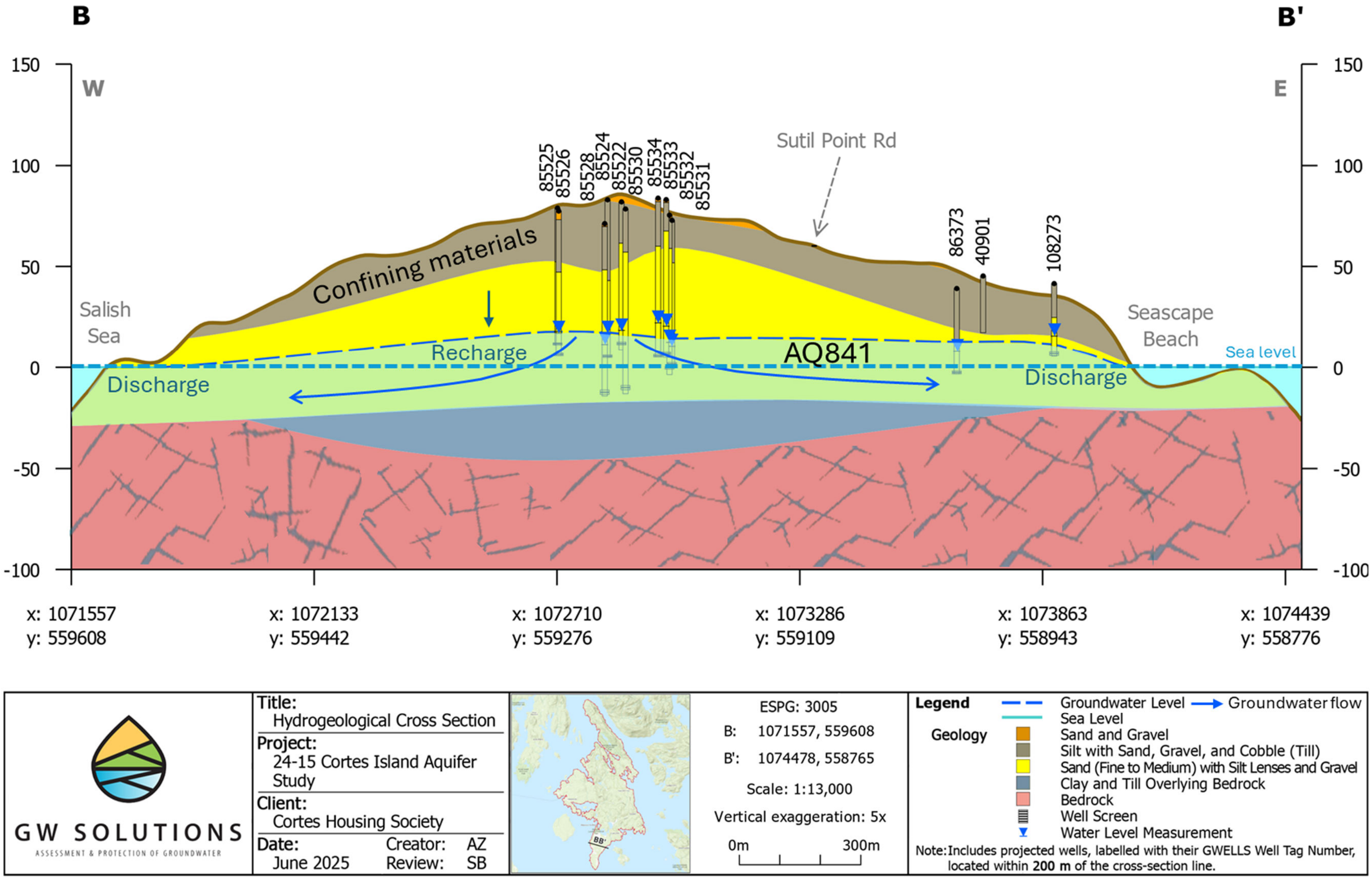


Figure 42. Cross-section B-B' AQ841 Manson's Landing.

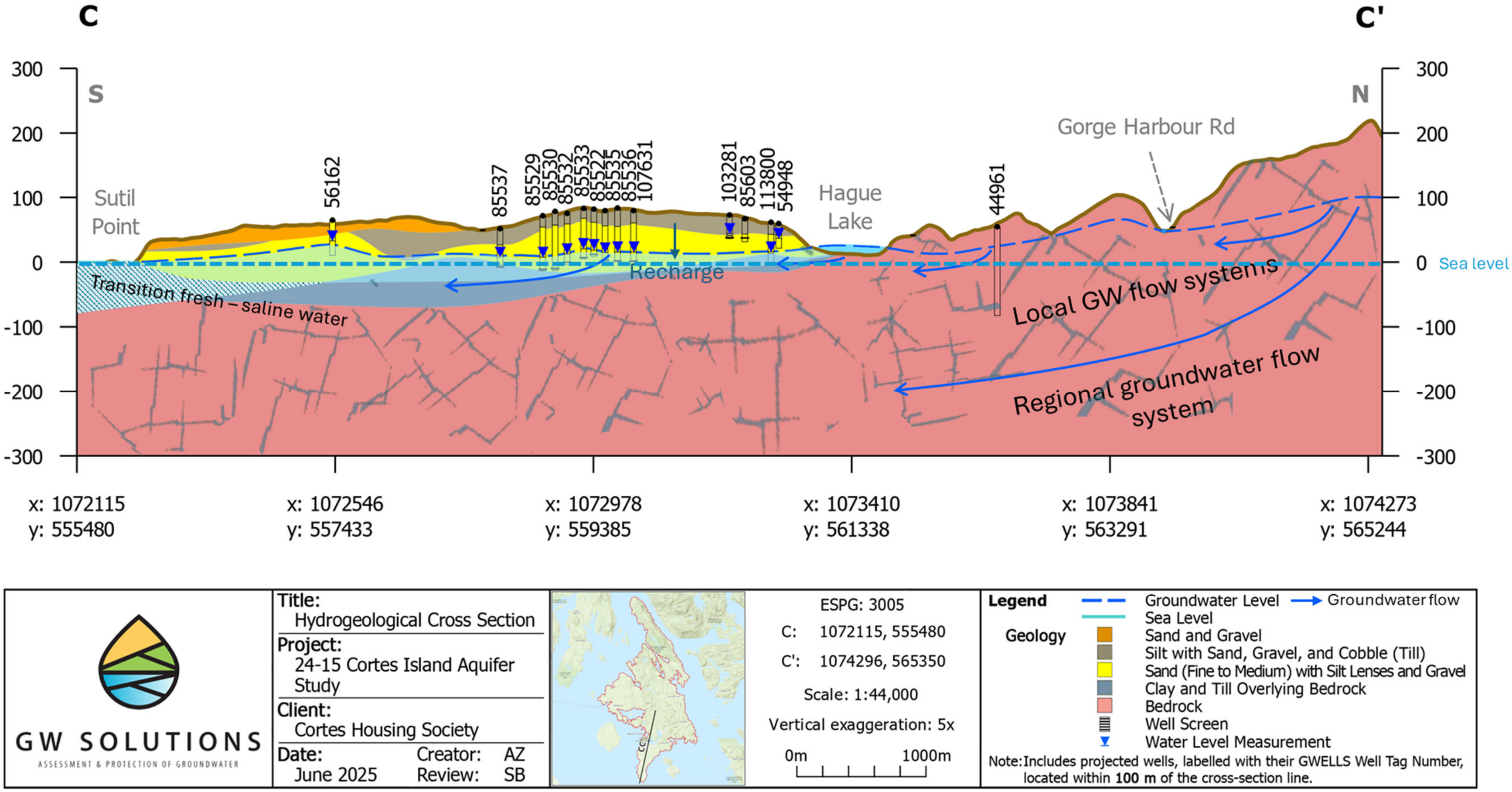


Figure 43. Cross-section C'C' Northeast of Manson's Landing to Sutil Point.

8.2 Whaletown Fractured Bedrock Aquifers

8.2.1 Aquifer Characteristics

Wells in the Whaletown area are mainly constructed in fractured granitic bedrock. Several small aquifers are mapped in this area including AQ843, AQ844, and AQ845 (Figure 46). These aquifers share similar properties and could potentially be consolidated into one aquifer.

The Whaletown water management area was delineated based on topographic or flow divides and encompassed the watershed area extending from an elevation of approximately 180 meters above sea level (masl) to sea level and the direction of groundwater flow is from upland areas downgradient to the southwest to coast of Whaletown Bay and southeast to Gorge Harbour (Figure 46). Wells registered in GWELLS range in depth from 3 to 183 m (10 to 600 ft) in depth with an average depth of 88 m (290 ft). Estimated well yields range from 1 to 340 L/min (0.25 to 90 USgpm), with an average of 12 USgpm. There are 51 registered wells corresponding to a moderate well density of 5 wells/km^2.

8.2.2 Water Availability and Use

Water use in this management area is primarily for residential use from private domestic wells. The Whaletown water system services 17 lots on the southeast side of Whaletown Bay. There are a small number of commercial and institutional users, including the BC Ferries Terminal, and the Gorge Harbour Marina and a commercial campground. Water use in the management area is estimated to be 79,000 m^3/year. Water stress for the region as a whole is ranked as low, however, there are some areas of higher well density and aquifers of small size, such as AQ845, where the aquifer stress is classified as moderate to high. Careful management of water systems, including monitoring groundwater levels and quality (salinity), metering of water use, and water conservation planning are critical in this region.

8.2.3 Vulnerability to Contamination

Aquifer vulnerability to contamination from the land surface in Whaletown is considered moderate to high. Soil and sedimentary layers overlaying the bedrock have an average depth of 9 m (29 ft), while the overburden is thin or absent in upland areas (Figure 47). Sources of contamination from land use are primarily sewage discharges to ground via septic systems.

8.2.4 Likelihood of Hydraulic Connection

Groundwater-fed springs, perennial wetlands, and shallow water tables within the Whaletown Commons area suggests that hydraulic connectivity between groundwater flow system and Whaletown Creek is likely. Whaletown Creek is not presently mapped within the provincial stream inventory and could be formally surveyed and delineated to improve understanding and protection of this water source. Other licensed springs in this area appear to be topographically controlled depression springs, occurring where there is a change in the slope of the ground surface, or contact springs, occurring where seepage concentrates at the interface between shallow overburden and low permeability bedrock below (Figure 44).

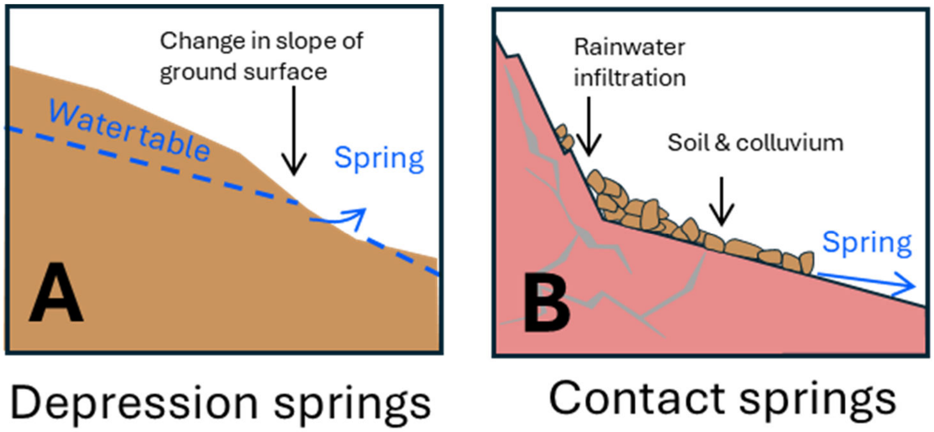


Figure 44. Mechanism of formation of A) depression springs and B) contact springs, adapted from (Kreye et al., 1996).

8.2.5 Seawater Intrusion Hazards

The vulnerability of fractured bedrock aquifers to SWI is expected to be greater in areas with a smaller upgradient recharge area, where there is a higher well density, and where wells are drilled deeper below sea level, and intersect fractures containing brackish (mixed) or saline water. Bedrock wells may have a lower productivity compared to wells in unconsolidated materials increasing the risk of over-pumping, while bedrock aquifers often have greater annual fluctuations in groundwater level and may be sensitive to overuse during drier periods when groundwater levels are deeper. For these reasons the overall hazard of SWI intrusion in the Whaletown management region is expected to be higher than in other areas of the island.

SWI impacted wells have been documented in AQ845 (Gorge Harbour) an area of higher well density and potentially higher water demand for both domestic and non-domestic (commercial) use. Increasing well setbacks from the coast, groundwater level and quality monitoring, water conservation and demand management are recommended to reduce the SWI hazard in this area.

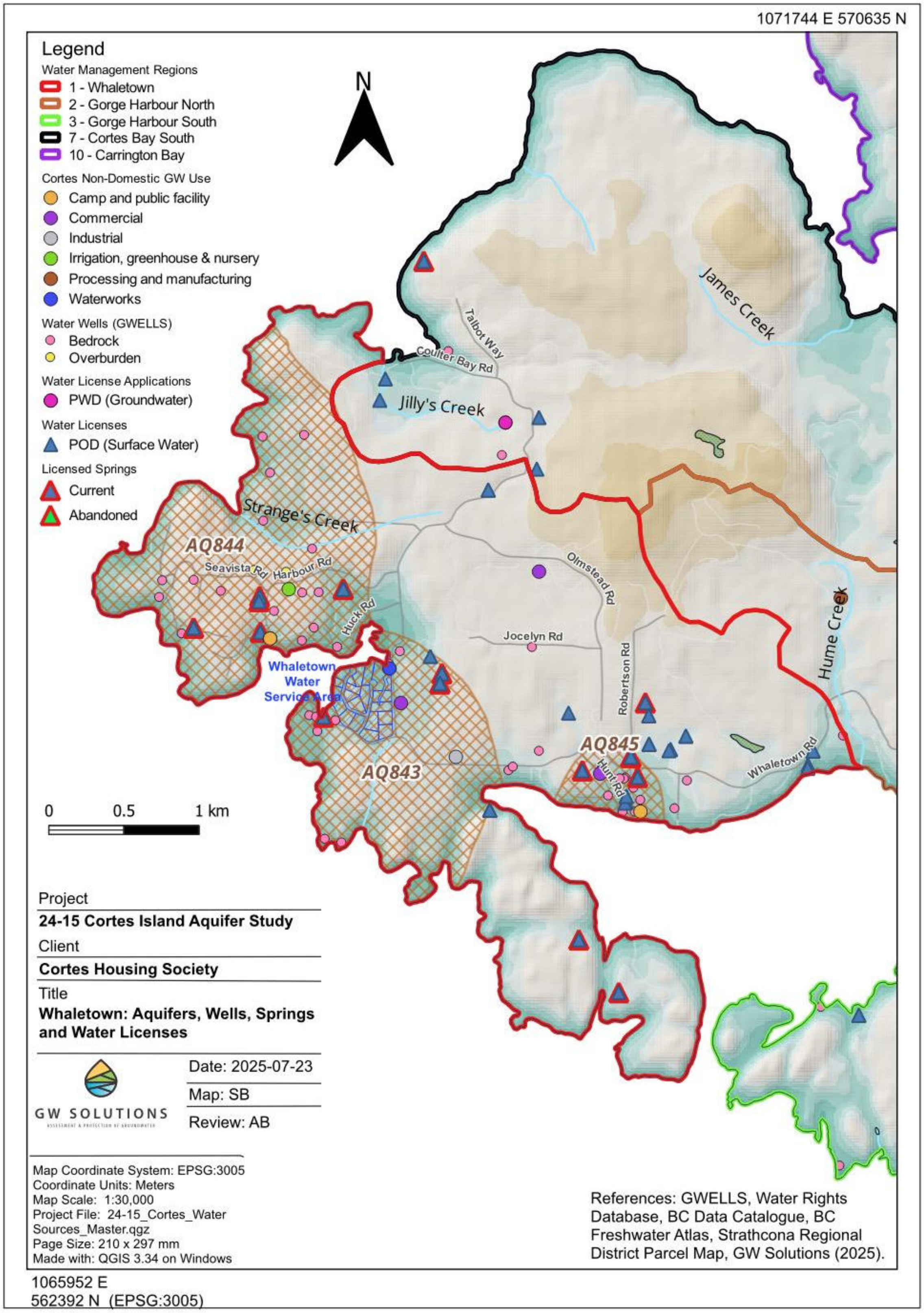


Figure 45. Whaletown aquifers and water sources.

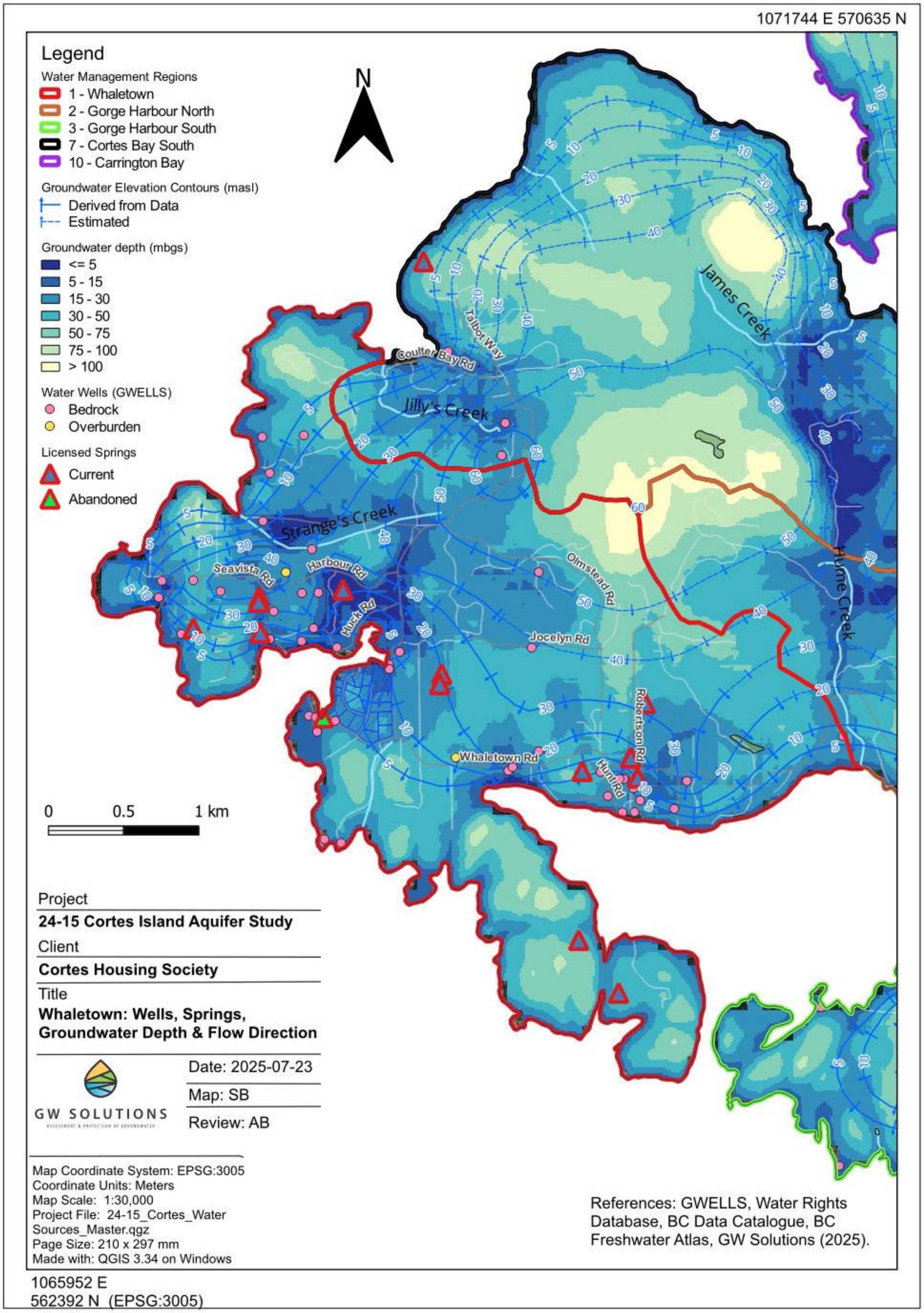


Figure 46. Whaletown region groundwater depth and flow direction.

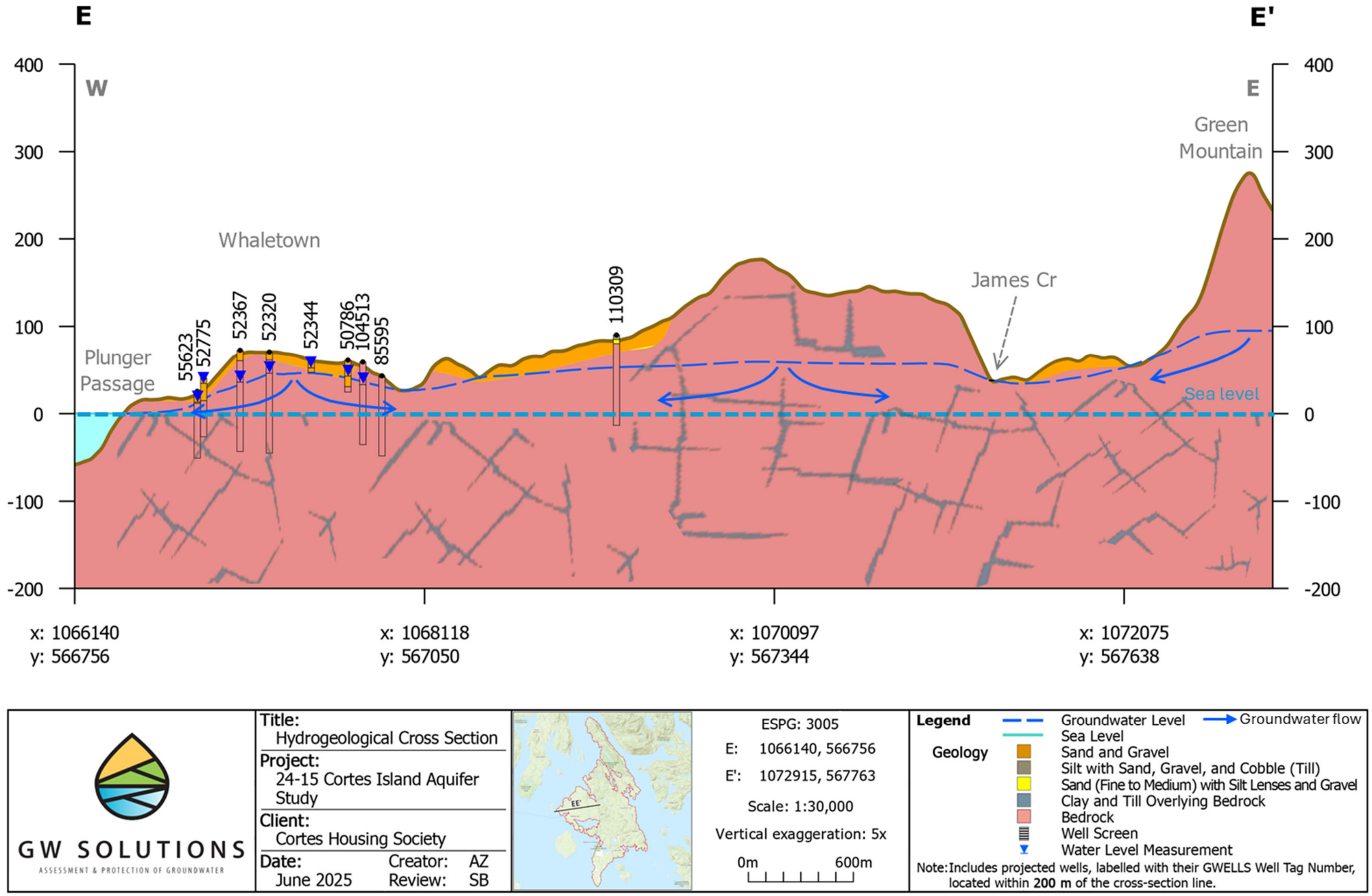


Figure 47. Cross-section E-E' Green Mountain to Whaletown.

8.3 Squirrel Cove

8.3.1 Aquifer Characteristics

The hydrostratigraphic model for Cortes Island identified and mapped the boundary of an unconsolidated aquifer in the Squirrel Cove area not currently included in the provincial aquifer inventory. The Squirrel Cove unconsolidated aquifer has an area of approximately 3.1 km^2 and is the water source utilized by domestic users and water systems in the Squirrel Cove area, including the Klahoose First Nation community.

The Squirrel Cove aquifer encompasses the moderately to gently sloped lands upgradient from the coast at Squirrel Cove, extending from the south side of Squirrel Cove Road to the northwest side of the Klahoose community (Tork Reserve). Surficial deposits in this area have a variable thickness up to 110 m (360 ft) deep. The sedimentary sequence from ground surface downward consists of a thin layer of soil or sandy deposits, a thick layered sequence of low permeability confining materials consisting of silt, clay, and compacted silty sand and gravel, overlying a permeable, water-bearing sand and gravel deposit which forms the unconsolidated aquifer. Below this, a lower confining unit comprised of clay or till, separates the unconsolidated aquifer from the underlying granitic bedrock.

The Squirrel Cove unconsolidated aquifer extent was delineated based on geologic mapping of surficial moraine materials and Quaternary deposits (Dunn and Thrift, 1983; Trettin, 2012), construction records of wells registered in the Groundwater Wells and Aquifers (GWELLS) database, and the 3D model which identified where overburden deposits are thicker and provide a usable source of water to wells drilled within the unconsolidated deposits. The aquifer boundaries were defined by the area of well development, the marine coastline on the east side, and on the west side by the 120 masl topographic contour. At elevations higher than 120 masl, the overburden is generally thinner, overlying bedrock ridges and knolls with steeper topography. The aquifer is heterogenous, and water-bearing layers are thinner or absent in some areas closer to the coast where some deeper wells are drilled through the overburden into the underlying fractured granitic bedrock formation. The aquifer boundaries are considered approximate and could be further refined if additional wells are drilled in this area.

The aquifer materials are described in well construction records as coarse gravel, silty gravel, sand, and silty sand. Depth to the aquifer is an average of 33 m (ranging from 0 to 91 m) below ground. The aquifer has an average thickness of 20 m. The aquifer stratigraphy is likely associated with Quadra sand glaciofluvial) or more recent post-glacial (Vashon) materials deposited in a coastal marine setting (Trettin, 2012).

The main source of aquifer recharge is from precipitation at the land surface. Some recharge may originate from mountain block recharge on the hillslopes to the west producing upward flow from the underlying bedrock aquifer to the unconsolidated aquifer.

The groundwater levels are moderately deep and the average reported static water level is 35.6 m (117 ft) below ground. The aquifer is hydraulically confined as the groundwater levels rise above the top of the aquifer. However flowing artesian wells, in which groundwater levels rise above the ground surface, have not been reported. The groundwater flow direction is southwest to northeast, from high to low elevation, based on topography and interpolation of static water levels measured in reported wells.

Five wells registered in the GWELLS database in this area are constructed in granitic bedrock, however there is no provincially mapped aquifer in this area. A preliminary boundary for a bedrock aquifer at Squirrel Cove was delineated based on the boundary of the Basil Creek watershed; groundwater flow is presumed to follow local topography and surface water divides. This aquifer was not assessed further given the limitations of the current data.

8.3.2 Productivity, Water Availability and Use

The productivity of the Squirrel Cove unconsolidated aquifer is considered moderate. Estimated well yields range from 1 to 20 USgpm, with an average of 10 USgpm based on air-lift testing by drillers when the wells were constructed. There are 10 registered wells drilled in the aquifer, corresponding to a low well density of 3 wells per km^2. Water use is estimated as 11,000 m^3/year and the aquifer stress is considered low.

8.3.3 Vulnerability to Contamination

The Squirrel Cove unconsolidated aquifer has a low vulnerability to contamination from the land surface. It is lithologically confined, and overlain by fine-grained sediments including clay, silt and till (dense silty sand and gravel) with an average thickness of 34 m (112 ft). The aquifer and static water level are relatively deep; the average depth to the top of the aquifer is 68 m (222 ft) below ground surface. Sources of contamination from land use are primarily sewage discharges to ground via septic systems.

8.3.4 Likelihood of Hydraulic Connection

Squirrel Creek and Basil Creek overlay the aquifer and drain towards Squirrel Cove. Limited information is available at this time to assess hydraulic connection; however, the Squirrel Cove unconsolidated aquifer has a thick confining layer, and relatively deep groundwater levels that reduce the likelihood of hydraulic connection with surface water.

8.3.5 Seawater Intrusion Hazards

In the Squirrel Cove area, the base of the unconsolidated aquifer is inferred to be above sea level on the south and north border of the aquifer. The central part of the aquifer may intersect the beach in central Squirrel Cove increasing vulnerability to SWI where the aquifer extends to the coast and below sea level. The steep topographic slope of the watershed, high rates of recharge and small number of wells in this area also suggest that the overall hazard of SWI for this aquifer is low.

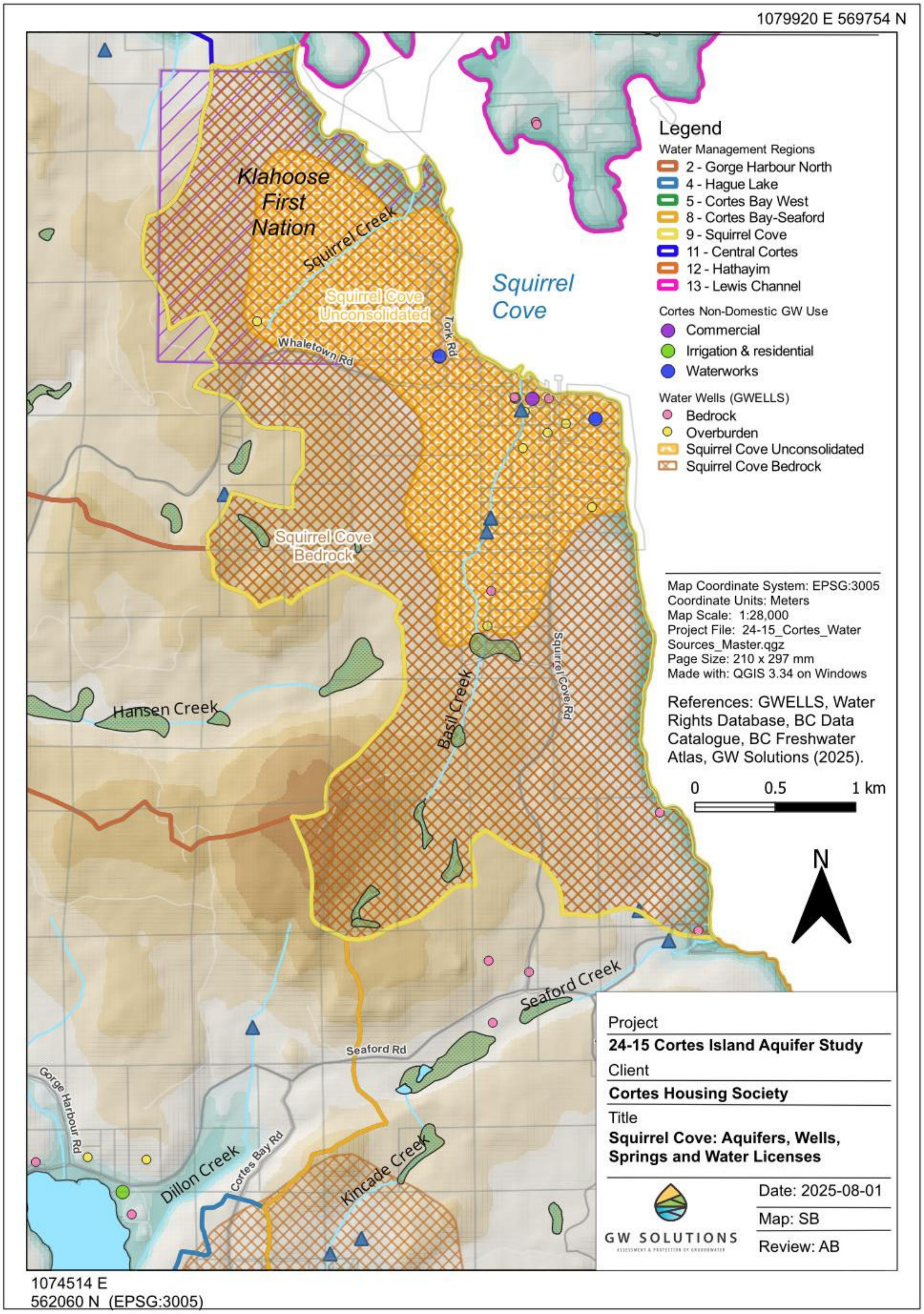


Figure 48. Squirrel Cove aquifers and water sources.

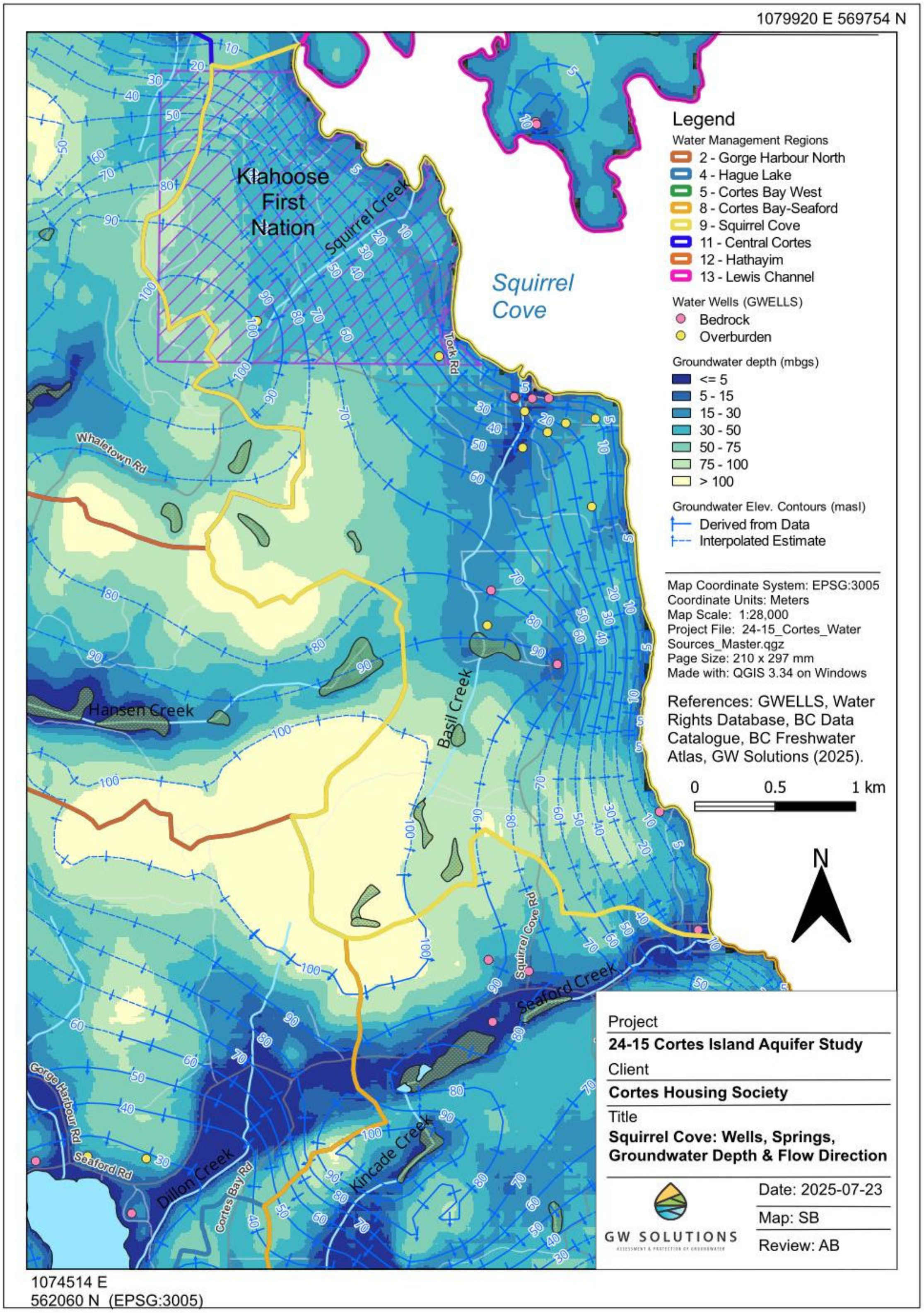
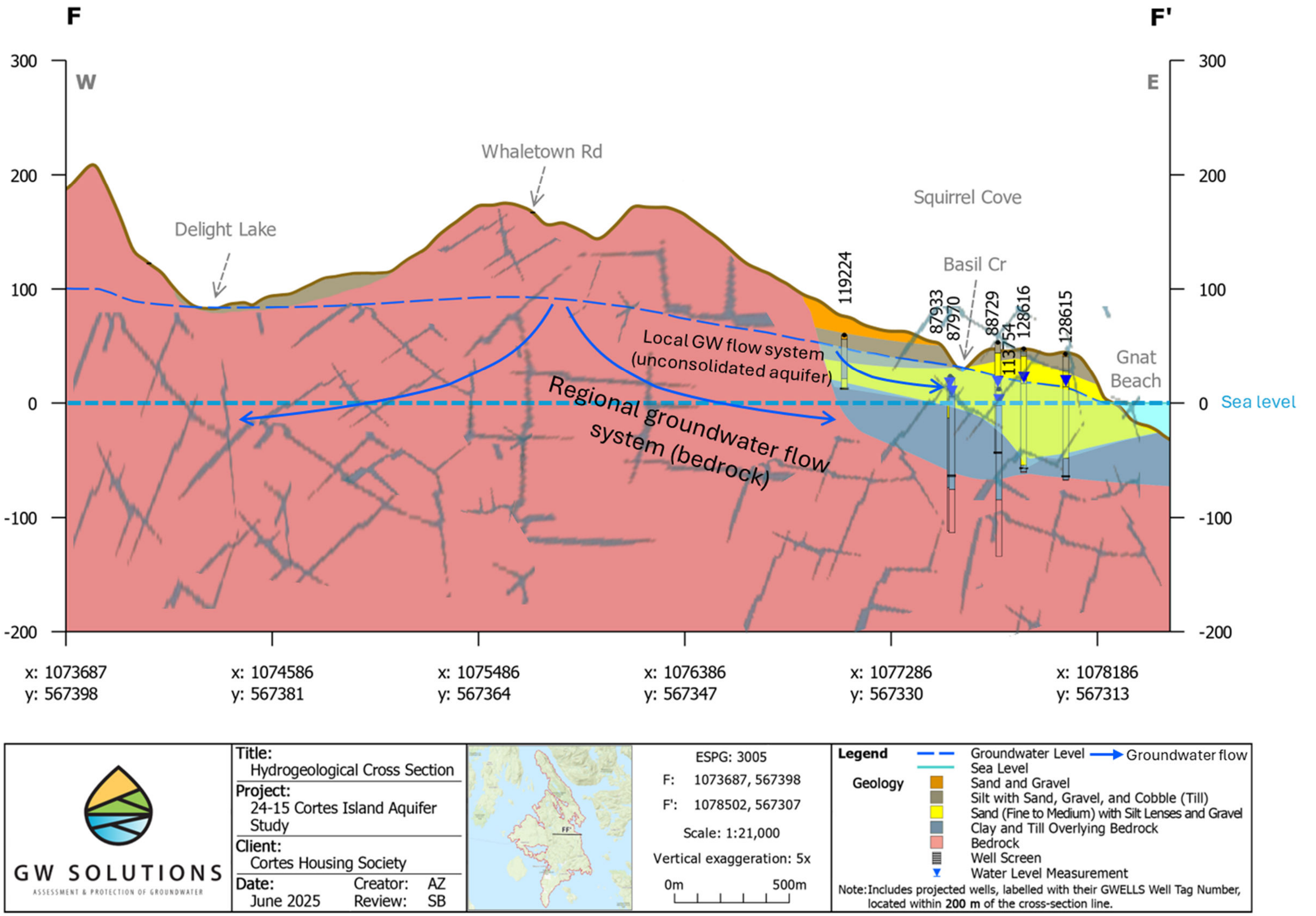


Figure 49. Squirrel Cove groundwater depth and flow direction.



Title: Hydrogeological Cross Section
Project: 24-15 Cortes Island Aquifer Study
Client: Cortes Housing Society
Date: June 2025 Creator: AZ
Review: SB

ESPG: 3005
F: 1073687, 567398
F': 1078502, 567307
Scale: 1:21,000
Vertical exaggeration: 5x
0m 500m

Legend
- Groundwater Level
- Groundwater flow
- Sea Level

Geology
- 🟧 Sand and Gravel
- ▨ Silt with Sand, Gravel, and Cobble (Till)
- 🟨 Sand (Fine to Medium) with Silt Lenses and Gravel
- 🟦 Clay and Till Overlying Bedrock
- 🟥 Bedrock
- ▤ Well Screen
- ▼ Water Level Measurement

Note: Includes projected wells, labelled with their GWELLS Well Tag Number, located within **200 m** of the cross-section line.

Figure 50. Cross-section F-F’ Green Mountain to Whaletown.

9 CONCLUSIONS AND RECOMMENDATIONS

This study characterized groundwater resources on Cortes Island, while examining aspects influencing water availability and sustainable use.

A comprehensive review and inventory of water sources on the island was compiled from multiple sources, including provincial mapping and inventories, the Groundwater Wells and Aquifers (GWELLS) and Water Rights databases, historical studies, field observations and local information sources. Cortes Island has abundant water resources, including lakes, streams, springs and aquifers. There are 101 active water licenses, 2 for groundwater sources, and 99 for surface water sources including 29 springs (29% of current licenses). There are 223 wells registered in the GWELLS database, with roughly half constructed in sand and gravel materials and half in bedrock. Through analysis of land use occupancy and water sources, it is estimated that there could be more than 300 unregistered wells on the island.

A three-dimensional geologic and water model was developed, to describe and evaluate local aquifers and the processes affecting water availability. Two new aquifers—one unconsolidated sand and gravel, and one fractured bedrock—were delineated in the Squirrel Cove area. The hydrogeologic model was used to prepare maps of aquifers, groundwater depth and flow, and cross-sections which enable interpretation of subsurface conditions, aquifer depth, vulnerability, and water movement within local and regional flow systems.

Focusing primarily on groundwater sources, a water balance model was developed to evaluate water availability based on climate factors including precipitation, evapotranspiration and aquifer recharge in comparison to current water demand. The potential for water to infiltrate and contribute to groundwater recharge was evaluated for aquifers and defined water management areas, depending on influences such as soils, sediment, and aquifer characteristics, topographic slope, vegetation and land cover, and locations of linear features such as faults which affect water movement within the bedrock system. Groundwater use was estimated based on land use categories. The ratio of water demand compared to groundwater recharge was assessed for aquifers and water management areas. Potential changes to the water balance under future climate change scenarios were also examined.

Diffuse recharge over the land surface is the main recharge mechanism for the sand and gravel aquifers. From 22 to 28% of precipitation is estimated to contribute to groundwater recharge in unconsolidated aquifers, mainly during the fall and winter period (Figure 51). Focused infiltration including along fault contacts in upland zones, uneven land surfaces and depressions contributes recharge to the fractured bedrock, with from 10 to 17% of precipitation estimated to contribute to the recharge of the fractured bedrock aquifers.

Annual total groundwater use on Cortes is estimated as 296,000 m^3/y, compared to 120,000 m^3/year licensed surface water use (excluding one large license for power generation), therefore groundwater use is roughly 1.5 times higher than surface water use. The region’s abundant rainfall, the presence of larger glaciofluvial aquifers, and numerous lakes and streams situate Cortes Island favorably with respect to water resources.

Water stress, assessed as the ratio between groundwater use and recharge, is considered low for defined water management areas on an annual basis (Figure 52). The mapped aquifers with small localized areas of high well density in the Whaletown and Gorge Harbour areas exhibit moderate to high water stress based on an annual water balance In all regions and aquifers. Seasonal water stress is likely to occur, due to the long dry period with minimal precipitation and recharge, during which water must be supplied from aquifer storage. Droughts and extended dry seasons under climate change scenarios are likely to increase the seasonal deficit emphasizing the importance of conservation and careful management. In other coastal islands rainwater collection and use of cisterns to pump and storage groundwater are incorporated to adapt to seasonal deficits, and similar approaches could be employed on Cortes.

Cortes Island has numerous lakes and river systems oriented along lowland valleys. Shallower groundwater levels highlight these areas as locations of groundwater discharge. Many of these valleys, such as the northeast trending Hague Lake, Gunflint Lake, and Slack Creek corridor are oriented along or intersect with linear geostructural features, indicating the locations of major faults or fracture systems. This suggests a strong probability of connectivity between the groundwater and surface water systems. In comparison, linear features and faults in upland areas are inferred to be locations of probable focused groundwater recharge.

The hydraulic connection between groundwater and surface water in the Manson’s Landing-Hague Lake area is considered likely. A proportion of runoff and shallow drainage in Manson’s Landing drains towards the lake, while the lake system may be perched above and contribute to recharge of both the deeper unconsolidated aquifer AQ841 and the underlying bedrock system where sand and gravel deposits are thinner. Understanding of this dynamic is hampered by a lack of monitoring data.

The connections between surface water lakes, streams, wetlands, and groundwater aquifers on Cortes Island could be the subject of further investigations, including student research studies. Establishment of integrated surface and groundwater monitoring networks would be valuable to begin to gather data within key areas of interest or concern. Management of groundwater pumping is critical to ensure adequate flow to hydraulically connected aquatic environments and maintain environmental flow needs.

The unconsolidated aquifers on the island have a lower vulnerability to contamination from the land surface, due to the presence of thick overlying lower permeability deposits such as silt, clay and till. In comparison, soils and sediments overlying fractured bedrock aquifers tends to be thinner, particularly in upland areas, increasing aquifer vulnerability to contamination. The most significant source of pollution on the island is sewage discharges from septic systems. Agricultural operations tend to be small and likely are not a significant source of nutrients or contaminants. However, employing environmental farm planning and best practices will help to reduce impacts of manure and farm waste on groundwater supplies (BC Agricultural Research and Development Corporation, 2021).

The sea water intrusion (SWI) hazard on Cortes Island is considered low overall, while the vulnerability is anticipated to be lower for unconsolidated aquifers, compared to fractured bedrock aquifers. Fractured bedrock aquifers are more vulnerable to SWI in areas with a smaller upgradient recharge area, where there is a higher well density, and where wells are drilled deeper below sea level, and intersect fractures containing brackish (mixed) or saline water. Wells in bedrock aquifers may have a lower productivity compared to wells in unconsolidated materials increasing the risk of over-pumping, while these types of aquifers typically have greater annual fluctuations in groundwater level and may be sensitive to overuse during drier periods when groundwater levels are deeper.

Areas on Cortes Island where current concerns related to seawater intrusion have been reported or identified include Cortes Bay (AQ842) and Gorge Harbour (AQ845). Properties bordering Cortes Bay tend to have relatively deep bedrock wells, with reported depths of up to 180 m (600 ft) below ground. Careful management is recommended to avoid over pumping of wells for domestic water supply or commercial operations (resorts, marinas) in this area. Consideration of alternate water sources including rainwater catchment may be considered for coastal lots with limited fresh groundwater supplies. Similarly, Gorge Harbour is an area of higher well density and potentially higher water demand for both domestic and non-domestic (commercial) use. Increasing well setbacks from the coast, monitoring groundwater levels and quality, water conservation and demand management are recommended to reduce the SWI hazard.

Based on the results of this study, the following recommendations are made:

- **Educate Well Owners Regarding Well Protection, Operation and Maintenance:** Proper well construction, maintenance and operation are critical for the protection and sustainability of groundwater resources. The *Water Sustainability Act*, Groundwater Protection Regulation (GPR) outlines the requirements for well drillers, pump installers and well owners to ensure wells are constructed and maintained properly, such installing and maintaining well caps and surface seals, grading, flood protection, and keeping the area around a well free of foreign matter which could contaminate the groundwater supply. Ensure wells are located at least 30 meters from potential contamination sources like septic systems. “Well Smart” workshops could be delivered to educate property owners on how to maintain and protect their wells from hazards such as contamination and seawater intrusion.
- **Promote Water Conservation:** Promote and increase awareness of water conservation within the community, especially during the summer periods of lower water availability and peak demand. The water systems and high-volume users should meter their water use and use the results to identify and quickly fix leaks, manage water demand and communicate with other water users regarding conservation. Irrigation workshops could be held for agricultural producers and gardeners to demonstrate water saving practices for food growing. Public education should also extend to tourists and part-time residents, and could include use of aquifer protection signage, billboards, conservation level notices and other methods to increase awareness.

- **Monitoring and Data Collection:** Develop a community monitoring network to monitor groundwater levels, including using volunteer wells to better assess aquifer conditions and changes over time within priority groundwater management areas. Establish integrated monitoring networks to collect data on surface water sources, including lake levels and streamflow so that hydraulically connected water sources can be managed conjunctively.

- **Groundwater quality assessment:** Complete a groundwater quality study of Cortes aquifers to evaluate the concentrations of natural contaminants (iron, manganese) and indicators of land use impact such as nitrate, or sea water intrusion (chloride, electrical conductivity). Well owners should be supported to test their water quality to ensure their water resources are safe and to identify and address water quality concerns.

- **Plan and implement shared infrastructure and services in areas of higher desired density:** Encourage local partnerships, including shared water and sewerage systems where appropriate, to optimize resource use and reduce individual costs while maintaining sustainable practices. Community water supply wells should be protected by siting them away from contaminant sources, and mapping well capture zones and protection areas. Ensuring minimum or enhanced setbacks of sewage systems from well protection areas will help proactively reduce the hazard of aquifer contamination from sewage waste.

- **Explore alternative water sources and storage options:** In areas of higher seawater intrusion hazard, consider use of rainwater harvesting systems and other non-traditional water sources to augment groundwater supplies. Water storage can also be developed to provide backup water supplies and to supply water for irrigation use.

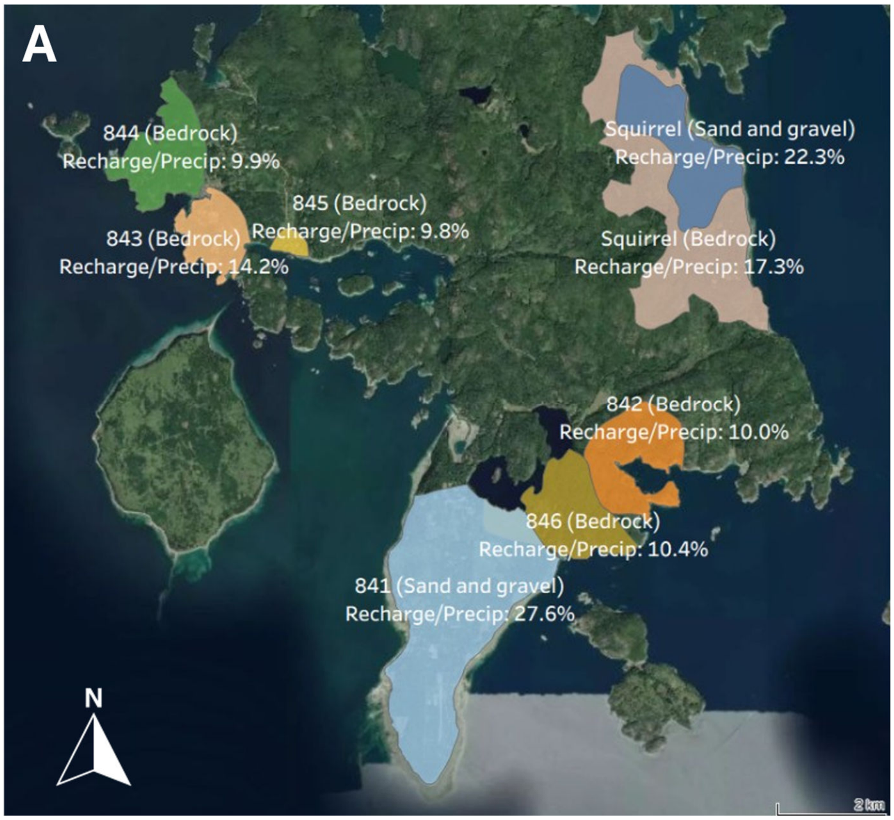
- **Improve education and management of domestic septic systems:** Ensure septic systems are installed properly with adequate drainage fields that are appropriately sized based on local soils and the number of household occupants. Complete regular septic system maintenance including pumping out of solids. Avoid disposing chemicals, fats, or non-biodegradable items in the septic system. Periodically pump out the septic tank to prevent overflow and system failure. In areas with lower suitability for septic field installations, consider wastewater options that reduce nutrient and contaminant impact on water resources (e.g. composting toilets, enhanced treatment options). “Septic Smart” workshops and education programs can help promote good septic system practices.

- **Improve well inventory and update aquifer mapping:** Encourage property owners to register their wells in the GWELLS database, and complete well surveys or inventories in priority areas. Provincial mapping could be updated to include newly identified aquifers and consolidate or evaluate aquifer boundaries where the mapping is outdated.

- **Complete a detailed LiDAR survey:** Understanding of the hydrogeology and detailed surficial topography of the island could be improved by completion of a high-resolution LiDAR survey. Potential sources of funding for this type of work could be sought from the province, regional district or forestry companies working in the area.

- ***Water Sustainability Act* and groundwater licensing:** Non-domestic groundwater users should be encouraged to apply for a groundwater license to secure their water rights, if they have not yet applied. The Ministry of Water, Land and Resource

Stewardship could work with the local community to improve understanding and awareness of groundwater licensing requirements.



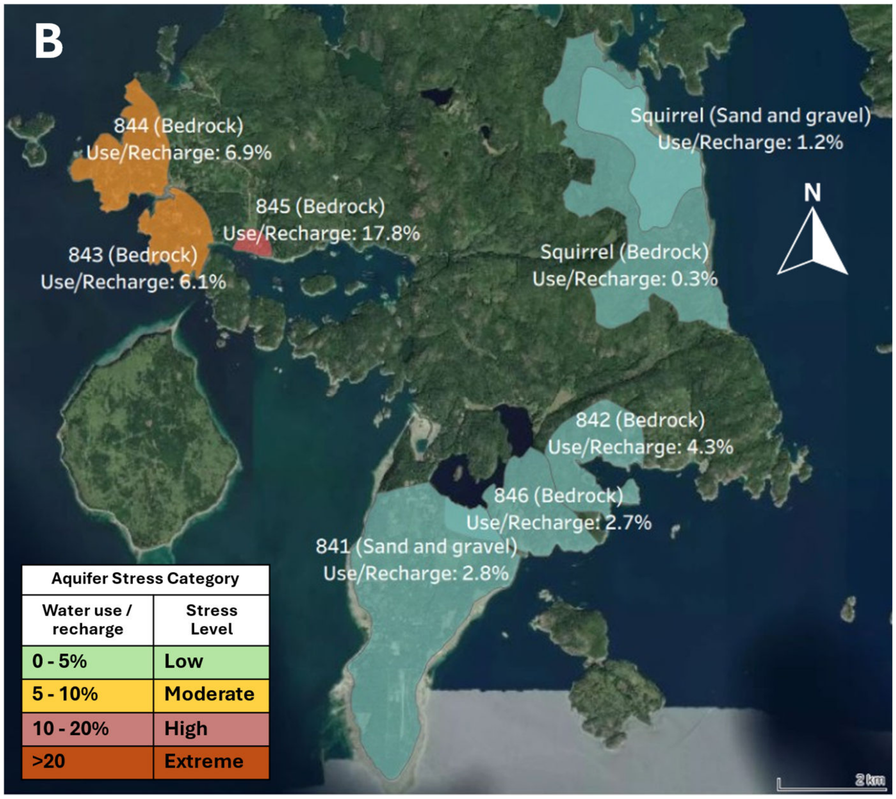


Figure 51. A) Percent of recharge from precipitation, and B) aquifer stress (water use vs recharge) for Cortes Island aquifers.

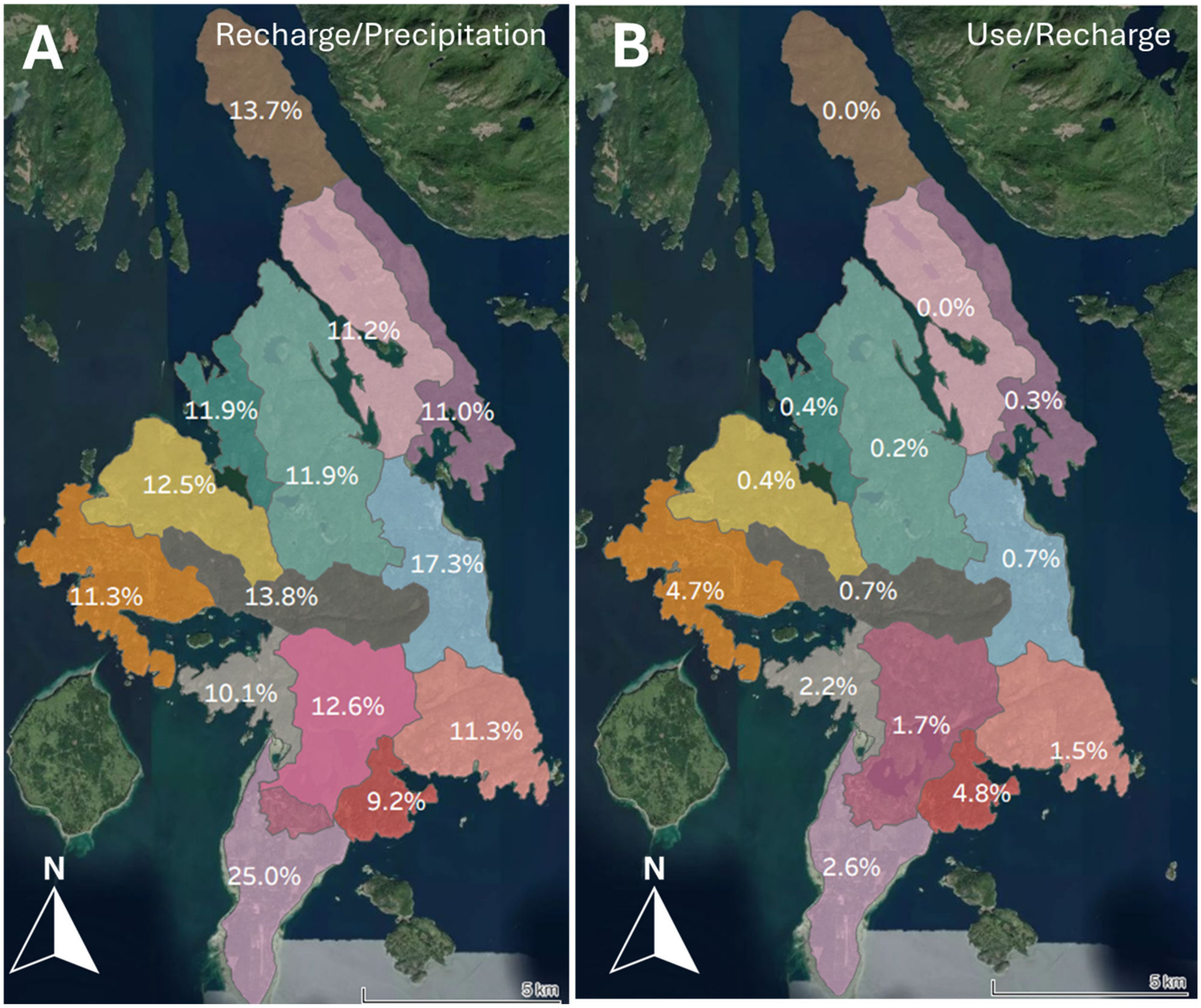


Figure 52. A) Groundwater recharge vs precipitation and B) Groundwater use vs recharge for Cortes Water Management Areas.

Study Limitations

This document was prepared for the exclusive use of Cortes Housing Society (CHS). The inferences concerning the data, site and receiving environment conditions contained in this document are based on information obtained during investigations conducted at the site by GW Solutions and others and are based solely on the condition of the site at the time of the studies. Soil, surface water and groundwater conditions may vary with location, depth, time, sampling methodology, analytical techniques and other factors.

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The findings and conclusions documented in this document have been prepared for the specific application to this project and have been developed in a manner consistent with that level of care normally exercised by hydrogeologists currently practicing under similar conditions in the jurisdiction.

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The produced graphs, images, and maps, have been generated to visualize results and assist in presenting information in a spatial and temporal context. The conclusions and recommendations presented in this document are based on the review of information available at the time the work was completed, and within the time and budget limitations of the scope of work.

CHS may rely on the information contained in this memorandum subject to the above limitations.

10 CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This letter report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix D.

GW Solutions was pleased to produce this document. If you have any questions, please contact the authors.

Yours truly,

GW Solutions Inc.

Engineers and Geoscientists BC Permit to Practice Number 1002916

S. L. BARROSO # 42631 2025.08.19

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APPENDIX A

BEST PRACTICES FOR PREVENTION OF SEAWATER INTRUSION

Table A1. Best practices for prevention of seawater intrusion.

Well Drillers	• Research local conditions and plan when drilling in areas at risk of seawater intrusion • Site wells a minimum of 30 m from seashore • Test for salinity indicators during drilling (electrical conductivity (EC) or total dissolved solids (TDS)) • If saline groundwater is encountered stop drilling and test the water quality • Backfill and seal off saline zones • Educate well owners regarding the hazards and prevention of SWI
Well Pump Installers	• Install well pump at shallower depth and include automated shutoffs to limit groundwater level drawdown below sea level • Set pump to operate for timed shorter cycles at a low pumping rate to refill water storage (“well sipping”) • Install meters and alarms to identify and quickly fix uncontrolled leaks • A datalogger can be installed that monitors groundwater level, temperature and EC, to develop an understanding of changes in water quality during pumping • Install monitoring equipment to measure EC or TDS while pumping, and to shut off pumping if water quality exceeds an identified limit (e.g. operational threshold or drinking water guideline) (Note: Cost for this type of monitoring would be relatively high and only recommended for a water supply systems or higher capacity production wells in which SWI impacts are being managed)
Well Owners	• Record observations that could indicate changes in water quality over time (salty taste, observed corrosion or discolouration of pipes and fixtures) • Purchase a low-cost water quality monitor (e.g. pen style conductivity or TDS meter) and record periodic measurements of groundwater quality, making note of trends, seasonal differences, or changes during periods of higher water use • Collect samples for lab analysis of geochemical water quality annually or semi-annually, and include analysis of salinity indicators (chloride, EC, TDS) • Install low water use fixtures (low flush or suction toilets, low flow shower heads and faucets) • Practice water conservation, limit non-essential water use including limiting outdoor irrigation in areas at highest risk of intrusion • Consider options for water re-use in the home or outdoors • Check for and fix uncontrolled leaks, hoses left open, etc. which could draw down water levels in the well • Educate residents and guests regarding low water use practices • Use water cisterns to store water from the well or other backup supplies (e.g., rainwater collection). Observing tank storage and drawdown is also an easy way to measure and manage water demand. • If well produces salty water seasonally or periodically, use an alternate supply, investigate the cause and seek advice from a driller, pump installer or other qualified person • Properly decommission (backfill) unused wells that could provide a pathway for circulation and movement of saline water from deeper to shallower aquifer zones • In multi-well systems, alternate the pumping of each well to allow water levels to recover

References:(Province of BC, 2016c; US Geological Survey, 2000; Werner et al., 2013).

APPENDIX B

GEOLOGY REFERENCE MAPS

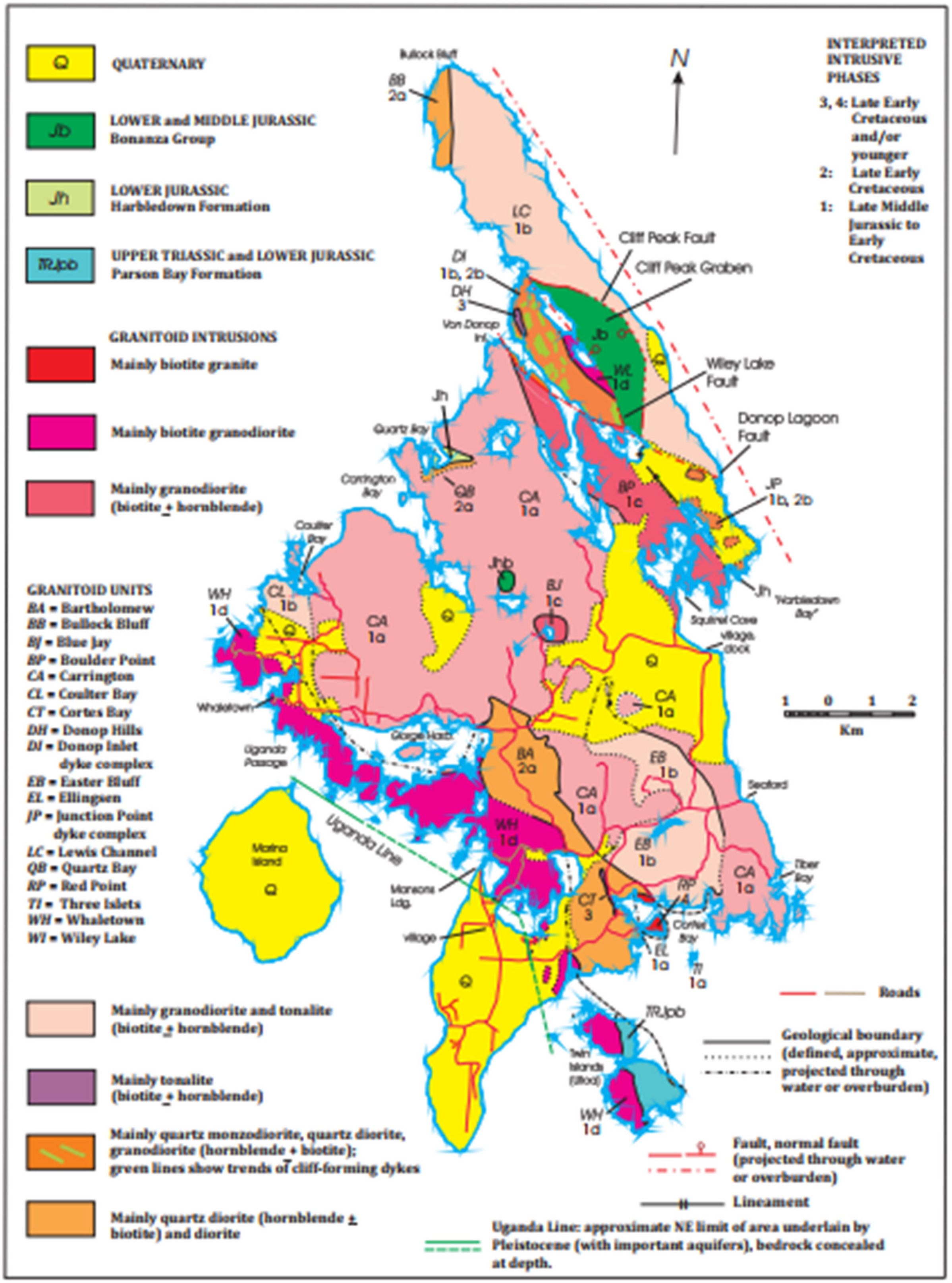


Figure B1:Cortes Island bedrock geology map, reproduced from (Trettin, 2012a)

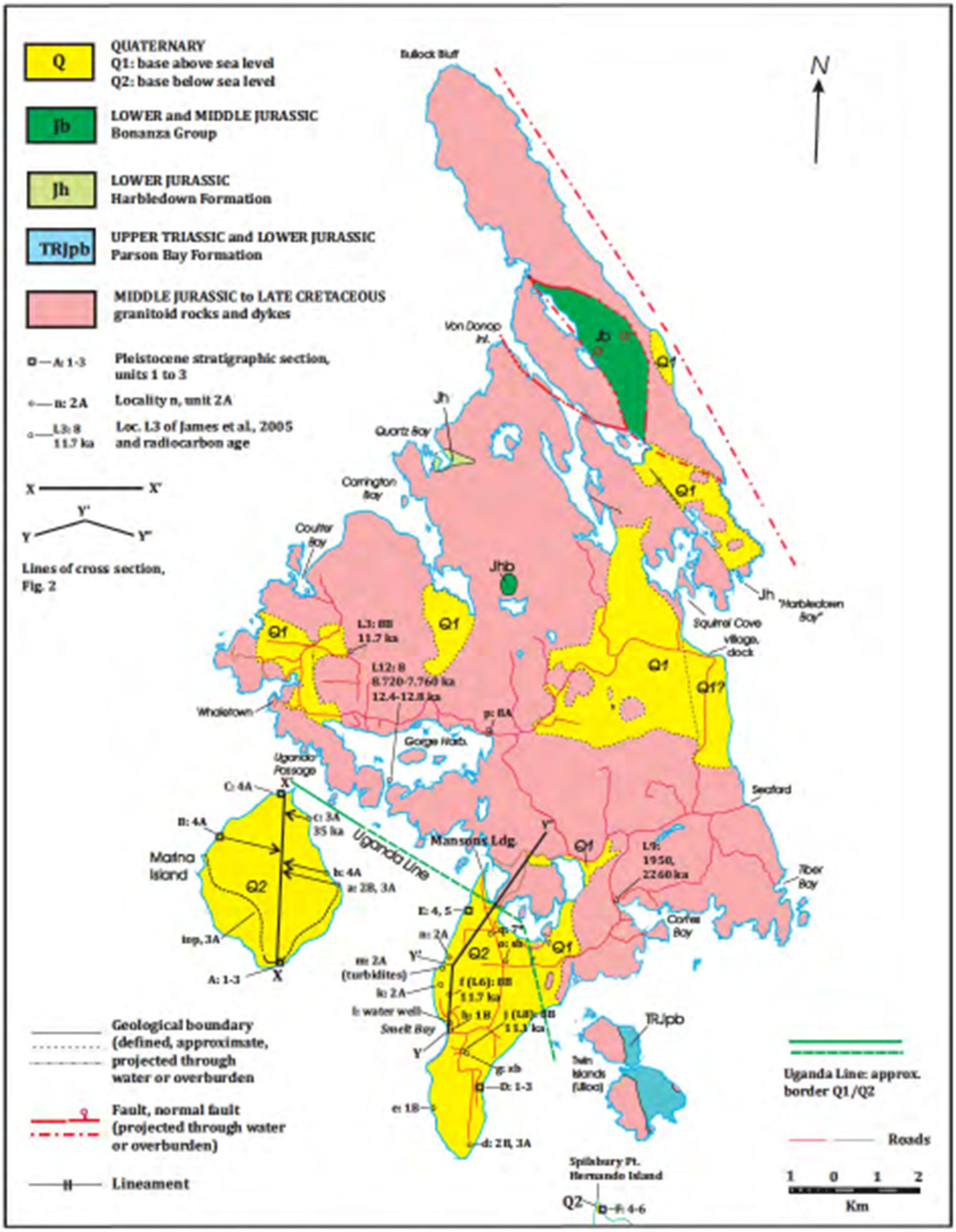
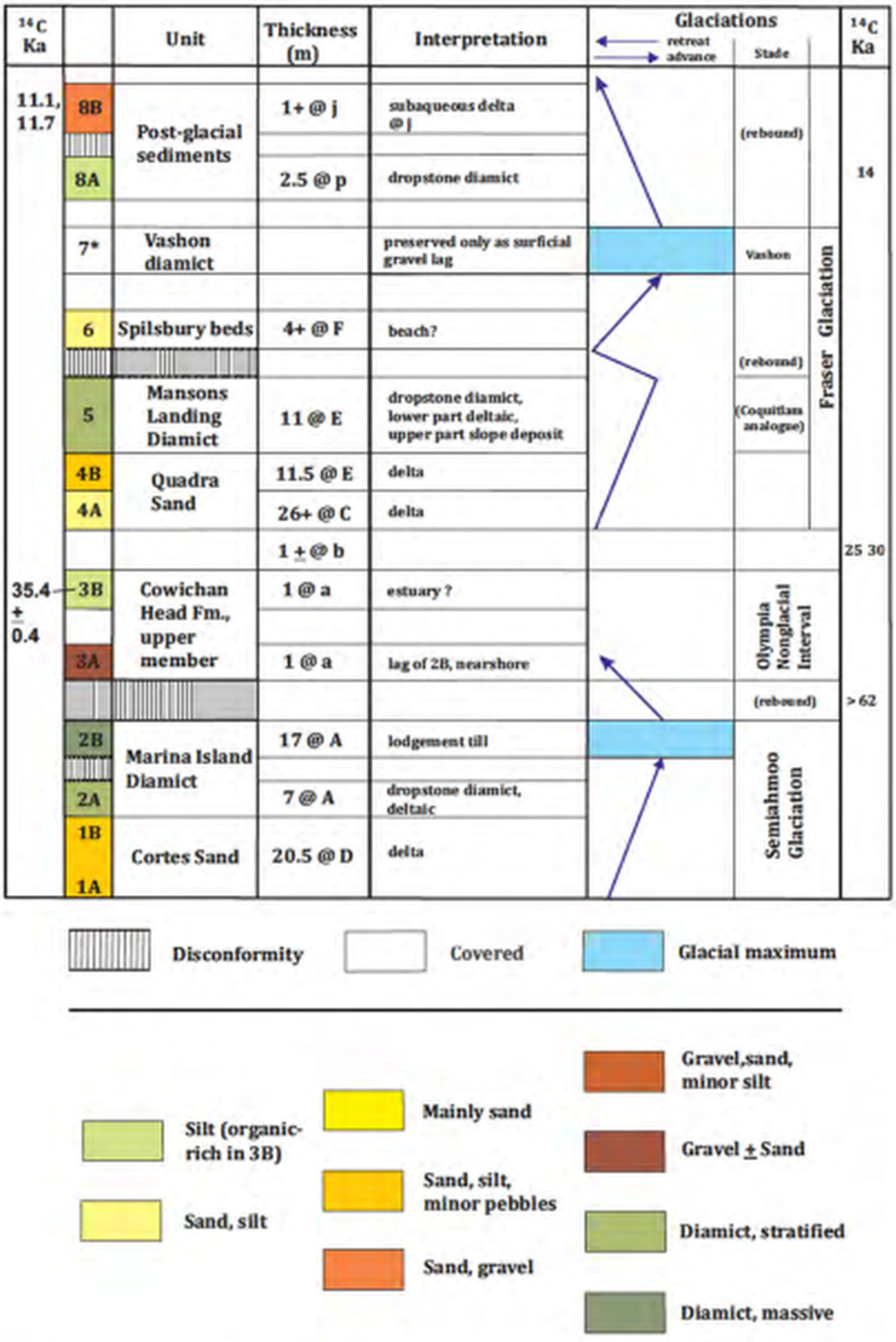


Figure 2-1. *Setting of Pleistocene sediments, stratigraphic sections, and other localities.*

Figure B2: Cortes Island Quaternary geology map, reproduced from (Trettin, 2012b)



14C Ka		Unit	Thickness (m)	Interpretation	Glaciations Stade		14C Ka
11.1, 11.7	8B	Post-glacial sediments	1+ @ j	subaqueous delta @ j	(rebound)		
	8A		2.5 @ p	dropstone diamict			14
	7*	Vashon diamict		preserved only as surficial gravel lag	Vashon	Fraser Glaciation	
	6	Spilsbury beds	4+ @ F	beach?	(rebound)		
	5	Mansons Landing Diamict	11 @ E	dropstone diamict, lower part deltaic, upper part slope deposit	(Coquitlam analogue)		
	4B	Quadra Sand	11.5 @ E	delta			
	4A		26+ @ C	delta			
			1 ± @ b				25 30
35.4 ± 0.4	3B	Cowichan Head Fm., upper member	1 @ a	estuary ?	Olympia Nonglacial Interval		
	3A		1 @ a	lag of 2B, nearshore			
					(rebound)		>62
	2B	Marina Island Diamict	17 @ A	lodgement till	Semiahmoo Glaciation		
	2A		7 @ A	dropstone diamict, deltaic			
	1B 1A	Cortes Sand	20.5 @ D	delta			

Figure 2-3. *Stratigraphic chart. (Radiocarbon years only for determination <50 Ka. Vertical axis not to scale.)*

Figure B3: Cortes Island Stratigraphic chart, reproduced from (Trettin, 2012b)

APPENDIX C

WATER BALANCE SUPPLEMENTARY TABLES

Table C1: Cortes Island Water Management Areas

Area	Management Area Name	Area (km^2)
1	Whaletown	10.3
2	Gorge Harbour North	8.8
3	Gorge Harbour South	4.3
4	Hague Lake	12.4
5	Cortes Bay West	3.4
6	Manson's Landing	8.5
7	Carrington Bay South	9.8
8	Cortes Bay-Seaford	9.5
9	Squirrel Cove	9.6
10	Carrington-Quartz Bay	4.6
11	Central Cortes	18.0
12	Hathayim	11.9
13	Lewis Channel	7.4
14	Northwest Cortes	8.8

Table C2: Cortes Island Non-Domestic Groundwater Users

Water use category	Facility or business name	Facility_Location	Aquifer material
Water system	BC Ferries - Cortes Island Terminal	Whaletown Road	Bedrock
Water system	BC Parks Smelt Bay Campground	Smelt Bay Cortes Island	Unconsolidated
Water system	Cortes Community Health Centre (Clinic)	947 Beesley Road Cortes Island	Unconsolidated
Water system	Cortes Island School	950 Beesley Road Cortes Island	Unconsolidated
Water system	Cortes Market	809 Sutil Point Road Cortes Island	Unconsolidated
Water system	Cortes Natural Food Co-Op Water System	800 Sutil Point Road Cortes Island	Unconsolidated
Water system	Cortes Island Motel (Georgia Strait Resorts)	1078 Seaford Road Cortes Island	Bedrock
Water system	Gorge Hall Whaletown Community Club	1375 Robertson Road	Bedrock
Water system	Gorge Harbour Marina Resort	1374 Hunt Road	Bedrock
Water system	Hollyhock Farm - Water	445 Highfield Road	Unconsolidated
Water System	Linnaea Farm Society	1255 Seaford Road	Unconsolidated
Water system	Good Libations	896 Hansen Road	Unconsolidated
Water system	Seattle Yacht Club At Cortes Bay (aka Cortes Bay Marine Resort)	1420 Red Granite Road	Bedrock
Water system	Manson's Hall (Southern Cortes Community Centre Water)	983 Beesley Road	Unconsolidated
Water system	Squirrel Cove Trading Co. Ltd. (Squirrel Cove General Store)	1611 Forrest Road	Bedrock
Water system	Whaletown Water System	Carrington Bay Road	Unconsolidated
Water system	Sunset Square Water System	800 Sutil Point Road	Unknown
Water system	Sunflower Commercial Kitchen Water System	521 Olmstead Road	Unconsolidated
Water system	Cortes Seniors Housing Society	951 Beesley Road	Unconsolidated
Water system	Cortes Community Housing Society Rainbow Commons	965 Beesley Road	Unconsolidated
Water system	Cortes Island Museum and Archives Society	957 Beesley Road	Unconsolidated
Water system	Klahoose (Tork 7 Reserve, Squirrel Cove, head of Toba Inlet)	1730 Tork Rd	Unconsolidated
Industrial	Emcon Services Highways Yard	1290 Gorge Harbour Road	Bedrock
Industrial	Gravel pit/cement manufacturing	Logging Road northeast off Robertson Road	UNK
Industrial	Qathen Xwegus Management Corp	1790 Tork Road, Squirrel Cove	Unconsolidated
Institutional	Cortes Island Firefighters Association (Hall 1)	959 Beesley Road	Unconsolidated

Water use category	Facility or business name	Facility_Location	Aquifer material
Institutional	Cortes Island Firefighters Association (Hall 2)	456 Whaletown Road	Unconsolidated
Farm	Fairhaven Gardens Landscaping/ Nursery (Fairhaven Farm)	1188 Bartholomew Road	Bedrock
Institutional	Vancouver Island Regional Library - Cortes Branch	1255 Seaford Road	Unconsolidated
Commercial	Whaletown Garden Centre	315 Harbour Rd	Bedrock
Commercial	Old Schoolhouse Art Gallery	1450 Carrington Bay Road	Bedrock
Commercial	Tai'Li Lodge, Kayaking, Luxury Accommodations	738 Ellingsen Way	Bedrock
Institutional	St Saviour-by-the-Sea Anglican Church	Cortes Bay Road	Bedrock

APPENDIX D

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these "General Conditions and Limitations".

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS's client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS's client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS's investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.